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The Biology of the Stalk Borer
Papaipema nebris (Gn.)

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ENTOMOLOGY SECTION

AMES, IOWA

CONTENTS

SUMMARY

1. The stalk borer, *Papaipema nebris* (Gn.), is a native American insect, normally feeding upon *Ambrosia trifida* but occasionally causing considerable damage to corn and other crops.

2. There is but one generation each year. The overwintering eggs hatch during late April or early May and after a growing period of from 9 to 18 weeks the larvae pupate. The moths emerge during August or September and begin at once to deposit eggs for the next year's brood upon the leaves of grass and weeds.

3. The number of larval instars required to complete development varied from seven to sixteen, average eight, depending upon the kind and quality of the food upon which the larva fed.

4. Natural enemies play an important part in holding this species in check.

5. The important parasites and predators are listed and some notes on their bionomics are given.

6. The elimination of the natural host plants of the borer from the fence row flora and the burning of infested fence rows and grasslands between Nov. 1 and May 1 are recommended as a means of control.

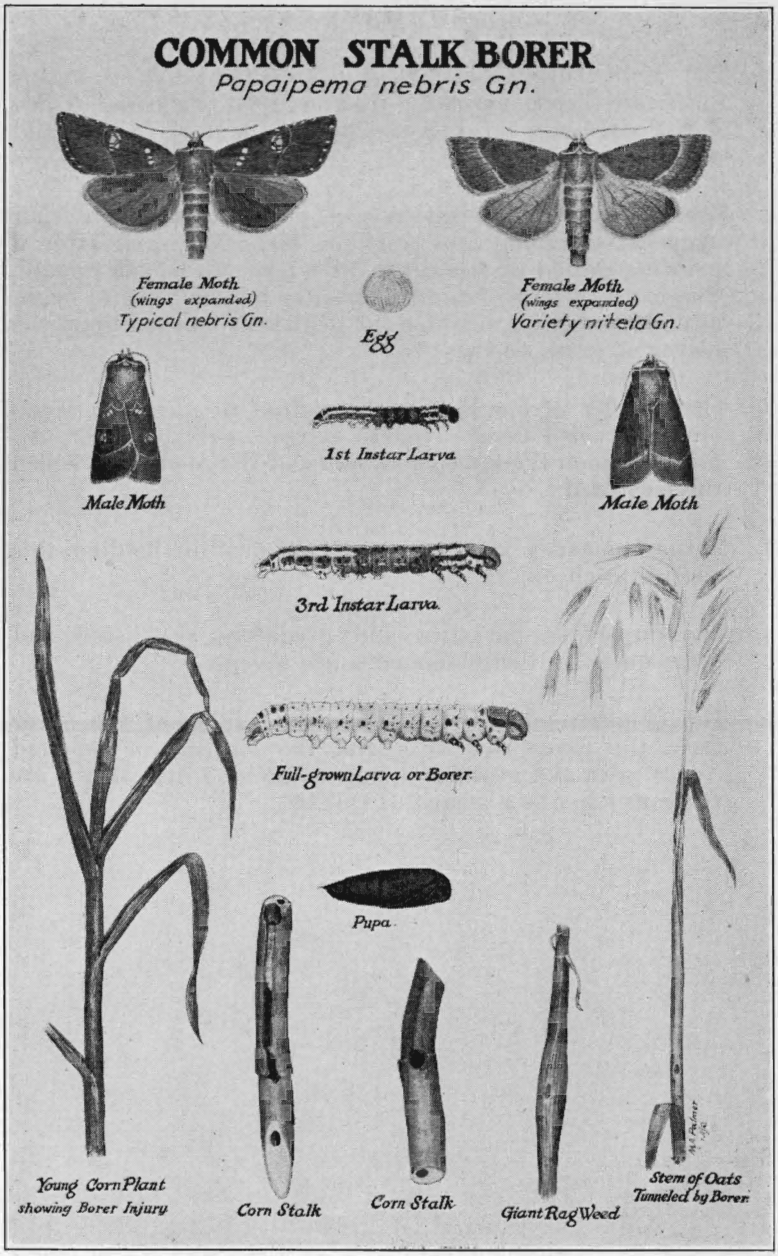

Fig. 1. The stalk borer, *Papaipema nebris* (Gn.), showing stages of life cycle.

The Biology of the Stalk Borer

Papaipema nebris (Gn.)

By George C. Decker[1]

The stalk borer, *Papaipema nebris* (Gn.) belongs to a large genus of noctuid moths, the larvae of which are borers in the roots or stems of annal and perennial plants, and from an economic standpoint it is by far the most important species of the genus. It is a native insect which normally feeds on wild grasses and weeds but readily attacks many cultivated plants where it attracts much interest from farmers and market gardeners. This is evidenced by more than 300 citations in literature and by numerous letters of inquiry received annually by various entomological organizations. In view of the general interest in this species and the extensive damage done by it in the last few years, it was deemed advisable to make a thoro study of its biology.

The data presented in the following pages are the result of studies made during the years 1926 to 1930, inclusive.

ECONOMIC HISTORY

THE STALK BORER

Papaipema nebris (Gn.)

The stalk borer, a native American insect, was mentioned as a pest in some of the earliest writings on economic entomology. Even prior to its description as a species by Guenée in 1852 we have three records of its doing considerable damage to crops. July 27, 1823, Thomas Beesley (2) of Cape May, wrote a letter to the editor of the American Farmer in which he described a worm that was eating into the wheat straws. In 1840 Jabez Jenkens (20) of West Whiteland, Penn., described the larva and its characteristic injury to wheat as follows: "I have not yet seen any published account of a new enemy that has made its appearance in the wheat this year. Many fields in Chester and Delaware counties, and perhaps elsewhere, have been in some degree injured by it. At mowing time when wheat was beginning to ripen, I walked into an adjoining field, when I observed a considerable number of dead heads, and standing

[1]The writer acknowledges valuable suggestions and criticisms offered by Dr. C. J. Drake, and other staff members of the Zoology and Entomology Department, Iowa State College. He is also indebted to Messrs J. M. Aldrich, R. A. Cushman, H. J. Reinhard, C. H. Curran, A. G. Gahan and J. C. Gilman for the identifying of parasites, to the late Dr. L. H. Pammel, Dr. G. O. Hendrickson and Miss C. King for identifying many of the host plants herein recorded, and to Messrs. Randall Latta and T. S. Hsiung for assistance in the field and in the laboratory.

in the worst discovered part, I plucked, without moving, six of them. On examination, a small hole was found in the upper joint of the stalk, and within, between that and the head, a worm about three-quarters of an inch in length, of a brown color, striped at both ends, and with a reddish head; it was very active. In some cases the worm had entered the stalk lower, but soon made its exit, boring another hole near the first, leaving such heads only partly injured." In 1848 T. W. Harris (19) described the larva and recorded that it was boring in potato vines. Asa Fitch (12) 1857 recorded it as boring in potato stems and noted that he believed it to be an undescribed species of the genus *Gortyna*.

In all of the foregoing records the identity of the pest was unknown, but fortunately the descriptions given are sufficiently accurate and complete so that there is little doubt but that *P. nebris* is the species concerned. Harris and Fitch both referred to the borer as common in potato vines and thus left the impression that they were quite familiar with it.

Dr. C. V. Riley (28) was first to recognize the borer as Guenée's species, and in 1867 he published a brief, tho partly erroneous account of its life history and habits, figures of the larva and the adult stages, and descriptions of the larva, pupa and adult. During the next 15 years Riley added many notes, most of which were published in the Missouri Entomological reports, the American Entomologist and various farm papers.

In 1871 Le Baron (21) reported the destruction of two acres of wheat at Madison, Wis., and according to Smith (43) 15 acres of corn were destroyed at Elmira, Ill., in 1877.

In 1905 Bruner (8) stated that wheat in the eastern half of Nebraska was severely damaged by the borer, and the same year (1905) Weldon (42) reported that the borer was a serious pest from Maine to Mississippi and west to Minnesota and Iowa.

From 1867 to date hardly a single year has passed that the stalk borer has not been reported as doing more or less damage. From 1902 to 1908 it received annual mention as one of the principal insects of the year in the Yearbook of the Department of Agriculture. Likewise, it has received annual mention in the Insect Pest Survey from its inauguration in 1922 to date. These reports indicate that the borer was abnormally abundant in 1904, 1905, 1908, 1923, 1926, 1927 and 1929.

In 1927 (Insect Pest Survey) the stalk borer was listed as one of the 10 most destructive insects of the year by three collaborators of the United States Bureau of Entomology, Insect Pest Survey.

In 1890, J. M. Shaffer (33) reported a general infestation of the borer in the vicinity of Keokuk, Iowa.

In 1923 the borer was very abundant in Iowa, and several fields of corn were seriously damaged. One 20-acre field of corn

Fig. 2. A field of corn damaged by the stalk borer, *Papaipema nebris* (Gn.).

near Marshalltown was completely destroyed. In 1926 and 1927 the borer was unusually destructive in all parts of the state and there were many reports of serious damage. One 40-acre field in Lee county was 80 percent destroyed. Altho there were many reports of injury in 1928 and 1929 the borer was not so abundant as during the previous two years.

In addition to the foregoing reports, E. A. Smith (34), Lintner (24), J. B. Smith (37), Washburn (39, 40), Bird (4, 5), and Lowry (25) have made valuable contributions to our knowledge of the life history and habits of this insect.

DISTRIBUTION

This species is widely distributed in the United States. Records show that it has a range extending from the Atlantic Coast west to the Rocky Mountains and from southern Canada and the New England states south to the Gulf of Mexico. It has been recorded as occurring in Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, Maine, Vermont, New Hampshire, Massachusetts, Connecticut, New York, Pennslyvania, New Jersey, Maryland, North Carolina, South Carolina, Georgia, Mississippi, Louisiana, Tennessee, Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Virginia, West Virginia, Nebraska, Iowa, Missouri, Kansas and Arkansas.

It has also been reported as occurring on celery in British Columbia (32); however, Mr. Max H. Ruhman of Vernon, B. C., the author of the above reference, has written to me as follows:

"There is considerable doubt as to the accuracy of this identification. The determination was made by the late R. C. Treherne from a single larva." With this information at hand and a knowledge of the habits of this insect, the writer feels certain that this was a case of incorrect identification, and the range of *P. nebris* is limited to the area east of the Rocky Mountains and possibly to the region east of the 100th meridian (the limit of many eastern species), for it is worthy of note that practically all reports from Nebraska and the Dakotas specify the eastern portions of these states.

The writer has collected stalk borers in all sections of Iowa and has records to show that it is a common pest in every county of the state. It seems probable that borers could be found on nearly every farm in the state. The distribution of the borer in Iowa is shown in fig. 3.

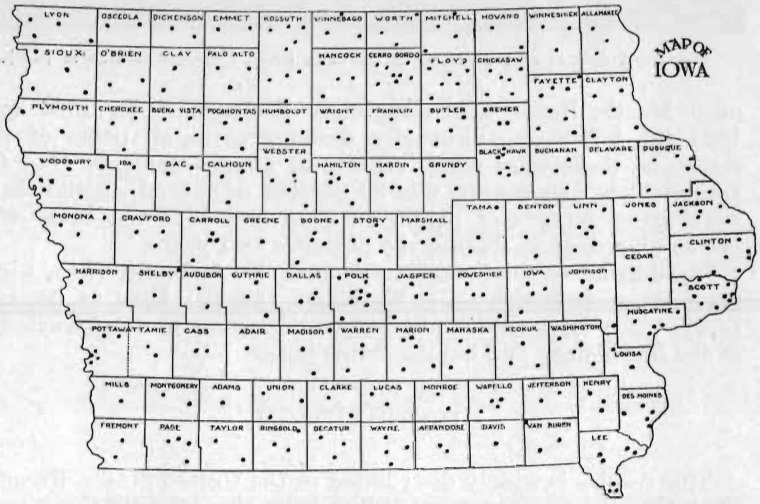

Fig. 3. Distribution of the stalk borer, *Papaipema nebris* (Gn.), in Iowa. (Corresponding records only. Personal observations would erroneously indicate heavy infestations in surveyed areas.)

HOST PLANTS

The stalk borer is a rather indiscriminate feeder and is known to attack 176 different species of plants, representing 44 families. Of these, 129 have been found as hosts of the borer in Iowa, and the remaining 47, altho not recorded here, have been cited in literature. In the early spring the larvae are most abundant in the grasses, but as they develop in size the small grass stems are found to be unsuitable to their needs, and about

July 1 they transfer their activity to a larger-stemmed plant. During this migration the larvae seem to show little preference in the selection of a host, readily accepting almost any succulent plant with a moderately large stem. More will be said concerning this problem of host selection under the heading "Larval Habits."

CLASSIFIED LIST OF THE HOST PLANTS OF *P. NEBRIS* AS RECORDED IN IOWA

Typhaceae
Typha latifolia L., Cat-tail.
Alismaceae
Alisma plantago-aquatica L., Water Plantain.
Graminaceae
Zea mays L., Corn.
Panicum scribnerianum Nash., Panic grass.
Setaria glauca (L.) Beauv., Pigeon grass.
Setaria viridis (L.) Beauv., Green foxtail.
Stipa spartea, Trin., Porcupine grass.
Muhlenbergia mexicana (L.) Trin.
Phleum pratense L., Timothy.
Agrostis alba L., Red top.
Calamagrostis canadensis (Michx.) Beauv., Blue joint grass.
Avena sativa L., Oat.
Triticum sativum Lam., Wheat.
Spartina michauxiana Hitohc., Slough grass.
Phragmites communis Trin., Reed grass.
Dactylis glomerata L., Orchard grass.
Poa pratensis L., Kentucky bluegrass.
Bromus inermis Leyes.
Bromus arvensis L.
Bromus tectorum L.
Agropyron smithii Rydb., Blue joint.
Agropyron repens L., Quack grass.
Hordeum jubatum L., Squirrel tail grass.
Elymus canadensis L., Wild rye.
Elymus robustus Scrib., F. J. G. Sm.
Cyperaceae
Carex vulpinoides Mich., Sedge.
Commelinaceae
Tradescantia reflexa Raf., Spiderwort.
Liliaceae
Lilium tigrinum Ker., Tiger lily.
Lilium sp.
Yucca filamentosa L., Adams needle.
Asparagus officinalis L., Asparagus.
Iridiscacea
Iris versicolor L., Large blue flag.
Iris sp.
Gladiolus sp.
Salicaceae
Salix nigra Marsh., Willow.
Salix cordata Muhl., Willow.
Salix longifolia Muhl., Willow.
Salix amygdaloides Anders., Willow.
Populus alba L., Poplar.
Populus deltoides Marsh., Poplar.

Urticaceae
Ulmus fulva Mich., Elm.
Ulmus americana L., Elm.
Ulmus fulva Mich., Elm.
Cannabis sativa L., Hemp.
Urtica gracilis Ait., Nettle.
Polygonaceae
Rumex crispus L., Curly dock.
Rumex mexicanus Meisn., Mexican dock.
Rumex altissimus Wood., Pale dock.
Polygonum lapathifolium L., Smartweed.
Polygonum pennsylvanicum L., Smartweed.
Polygonum persicaria L., Smartweed.
Polygonum convolvulus L., Black bind weed.
Fagopyrum esculentum Moench., Buckwheat.
Rheum rhaponticum L., Rhubarb.
Chenopodiaceae
Chenopodium album L., Lamb's quarters.
Spinacia oleracea L., Spinach.
Beta vulgaris L., Beet.
Beta vulgaris, Sugar beet,
Amaranthaceae
Amaranthus retroflexus L., Green pigweed.
Nyctaginaceae
Oxybaphus nyctagineus (Michx.) Sweet., Wild Four O'Clock.
Caryophyllaceae
Saponaria officinalis L., Bouncing Bet.
Ranunculaceae
Ranunculus sp., Buttercup.
Thalictrum dasycarpum Fisch. & Lall., Meadow rue.
Anemone canadensis L., Anemone.
Delphinium penardi Ruth., Prairie larkspur.
Peonia spp., Peony.
Saxifragaceae
Ribes aureum Pursh., Missouri currant.
Rosaceae
Crataegus spp.
Potentilla arguta Pursh., Five- finger.
Potentilla monspeliensis L., Five-finger.
Rubus idaeus L., Wild raspberry.
Rosa pratincola Greene, Prairie Rose.
Prunus virginiana L., Choke cherry.
Leguminosae
Melilotus officinalis (L.) Lam., Y. Sweet clover.
Melilotus alba Dear., W. Sweet clover.
Medicago sativa L., Alfalfa.
Petalostemum purpureum (Vent.) Rydb., Prairie clover.
Phaseolus vulgaris L., Bean.
Anacardiaceae
Rhus glabra L., Sumach.
Aceraceae
Acer negundo L., Box elder.
Vitaceae
Vitis vulpina L., Frost grape.
Malvaceae
Althaeae rosea, Hollyhock.
Onagraceae
Oenothera biennis L., Evening primrose.

Umbelliferae
Osmorhiza longistylis (Farr.) Dc., Sweet Cicely.
Pastinaca sativa L., Parsnip.
Primulaceae
Steironema lanceolatum (Walt.) Gray.
Apocynaceae
Apocynum androsaemifolium L., Dogbane.
Polemoniaceae
Phlox pilosa L., Phlox.
Labiatae
Teucrium canadensis L., wood sage.
Agastache nepetoides (L.) Htze., Giant hyssop.
Leonurus cardiaca L., Motherwort.
Monarda mollis L., Horse mint.
Solanaceae
Lycopessicum esculentum Mill., Tomato.
Solanum tuberosum L., Potato.
Solanum melongena L., Eggplant.
Physalis pubescens L., Ground cherry.
Physalis lanceolatum Michx., Ground cherry.
Nicotiana tabacum L., Tobacco.
Scrophulariaceae
Verbascum thapsus L., Mullein.
Veronica virginica L., Culver's Root.
Plantaginaceae
Plantago rugelli Done., Plantain.
Caprifoliaceae
Sambucus canadensis L., Elder.
Compositae
Solidago canadensis L., Golden-rod.
Solidago rigida L., Golden-rod.
Solidago sp., Golden- rod.
Aster cordifolius L., Aster.
Aster laevis, L., Aster.
Aster multiflorus Ait., Aster.
Aster sp., Cultivated aster.
Erigeron canadensis L., Horse weed.
Silphium laciniatum L., Compass plant.
Iva xanthifolia Nutt, Marsh elder.
Ambrosia trifida L., Great Ragweed.
Ambrosia artemisiifolia L., Lesser Ragweed.
Xanthium commune Britt., Cocklebur.
Heliopsis scabra Dunal., Ox-eye.
Rudbeckia hirta L., Black-eyed Susan.
Brauneria purpurea, Purple Cone-Flower.
Lepachys pinnata (Vent.) T. & G.
Helianthus annuus L., Sunflower.
Helianthus occidentalis, Riddel.
Helianthus grossesserratus Martens.
Helianthus tuberosus L., Jerusalem artichoke.
Dahlia spp., Dahlia.
Bidens frondosa L., Beggar-tick.
Bidens cernua L., Stick-tight.
Achillea millefolium L., Yarrow.
Cacalia tuberosa Nutt., Indian plantain.
Calendula officinalis L., Marigold.
Arctium minus Bernh., Burdock.
Cirsium iowense (Pammel) Fernald., Iowa thistle.

ADDITIONAL HOST PLANTS OF *P. NEBRIS* THAT HAVE BEEN MENTIONED IN LITERATURE BUT THAT HAVE NOT BEEN RECORDED AS HOSTS IN IOWA

Graminaceae
Secole cereale L., Rye.
Hordeum sativum Jessen., Barley.
Liliaceae
Lilium superbum L., Lily.
Lilium candidum L., Madonna Lily.
Cannaceae
Canna sp., Canna.
Piperaceae
Piper sp., Pepper.
Polygonaceae
Rumex britannica L., Great Water Dock.
Chenopodiaceae
Chenopodium suptarium.
Caryophyllaceae
Dianthus sp., Carnation.
Ranunculaceae
Ranunculus acris L., Fall buttercup.
Delphinum sp., Golden Larkspur.
Cruciferae
Brassica oleracea L., var. *Botrytes* Dc., Cauliflower.
Saxifragaceae
Ribes sp., Gooseberry.
Ribes nigrum L., Black currant.
Rosaceae
Spiraea sp., Spiraea.
Pyrus malus L., Apple.
Fragaria sp., Strawberry.
Rubus sp., Blackberry.
Rosa sp., Rose.
Prunus persica L., Peach
Prunus domestica L., Plum.
Leguminosae
Trifolium pratense L., Red clover.
Phasealus multiflorus Wild., Scarlet Runner Beans.
Pisum sativum L., Pea.
Euphorbiaceae
Ricinus communis L., Castor Bean.
Aceraceae
Acer saccharinum L., Silver maple.
Vitaceae
Vitis sp., Grape.
Malvaceae
Hibiscus sp., Rose mallow.
Cassypium herbaceum L., cotton.
Umbelliferae
Apium graevolens L., Celery
Oleaceae
Fraxinus sp., Ash.
Asclepiadaceae
Asclepias sp., Milkweed.
Polemoniaceae
Phlox sp.
Labiatae
Salvia sp., Sage.

Collinsonia canadensis L., Stone root.
Bignoniaceae
Catalpa bignonioides Walt., Catalpa.
Curcurbitaceae
Cucumis melo L., Muskmelon.
Compositae
Bellis sp., Daisy.
Callisterphus chinensis Ness., China Aster.
Xanthium strumarium L., Cocklebur.
Rudbeckia laciniata L., var. Golden- glow.
Cosmos bipinnatus Cav., Cosmos.
Gaillardia sp.
Chrysanthemum eucanthemum L., Marguerite.
Chrysanthemum sp.
Cirsium arvense, Canada thistle.
Cirsium sp., thistle.

CHARACTER OF INJURY

The nature of the injury inflicted by the borer varies considerably, depending upon the kind and the age of the host, as well as the age of the larvae.

In the early spring the newly hatched larvae usually enter the nearest suitable host plant, and since the grasses are the dominant form of vegetation at this time they are most noticeably affected altho a great many seedling weeds are also attacked. The larvae usually enter the grasses by crawling under a leaf sheath and boring into the stem, but they may also bore straight in thru the leaf sheath or crawl to the top and work down into the heart of the plant. When working within the stem the larvae frequently cut it off entirely, leaving the dead head in place suspended by the leaf sheath. This is especially noticeable in bluegrass during early June. In seedling weeds, the young larvae usually work as leaf miners. They work their way to the midrib and down thru the petiole into the main stem, but occasionally the "mine" may be deserted after which larvae migrate to the main stem or even to a new plant where they burrow into the main stem.

Regardless of the type of plant first attacked the larvae sooner or later kills it or outgrows it; i.e., it develops to such size that the diameter of the stem will no longer accomodate the borer. The larvae then migrates usually under cover of darkness, to a new host. It may or may not complete its development in its second host, depending on the size and rate of development of the particular host selected.

Large stemmed grasses, particularly those cultivated as cereal crops, may be attacked by newly hatched larvae, but more often they become infested by migrating caterpillars which burrow in almost anywhere between the base and the

Fig. 4. Corn plants showing characteristic injury produced by borers working in the stalk. Note the entrance holes and the withered tops of the plants.

head of the plant, apparently entering the internodes or nodes without showing very much choice. Once in the stem, they burrow upward leaving nothing but the outer wall of the stem so that the heads fail to fill and soon turn yellow while the rest of the plant remains healthy and green.

Corn is usually attacked when it is 2 inches to 2 feet high. Altho a few first instar larvae have been found feeding on the upper epidermis and in the midribs of young leaves, this plant is attacked most often as a second host. Injury to the young plants is typically of two forms. In one case the larvae burrows into the side and then upward thru the center of the stalk, eating away the heart of the plant so that the upper leaves, which are cut off from below, soon wilt and die (see fig. 4). This type of injury, in which the central portion of the plant appears dead while the outer leaves are green and apparently healthy, is commonly known among the farmers as "dead heart." In the other cases the larvae climbs to the top of the plant and then descends into the open heart where it feeds upon the rolled leaves and the bud of the plant. As a result of such feeding irregular rows of ragged holes appear in the leaves as they unfold (see fig. 5). Both methods of attack frequently result in the destruction of the developing tassel and the deformation of the upper part of the plant. Corn that has successfully passed the so-called "spindle-

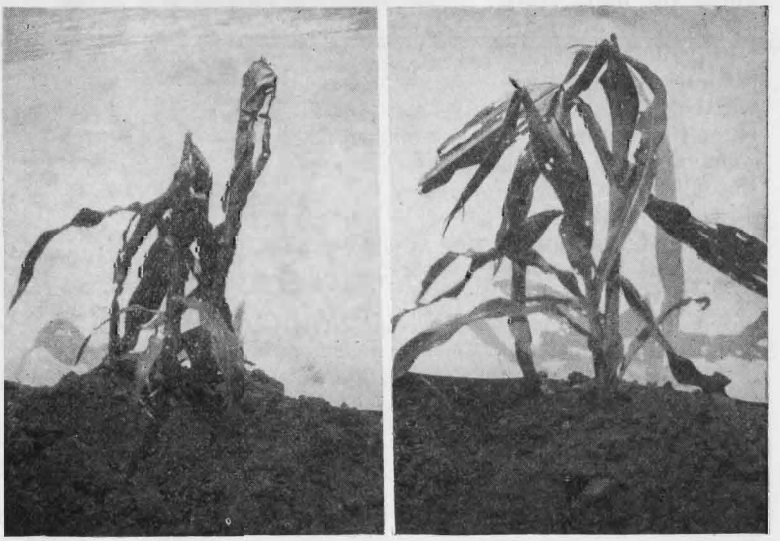

Fig. 5. Corn plants showing characteristic injury produced by borers working in the "heart" and tops of the plant. Note the ragged appearance of the leaves.

stage'' is not so seriously damaged by the borer. Altho it may make larger burrows in the main stalk the plant seems to be able to overcome its effects. Borers have been found in every part of the stalk from the root to the tassel and even in the center of the cobs (see fig. 6.) In the peach, willow, elm and other woody plants the borers attack only the terminal portion of the current season's growth.

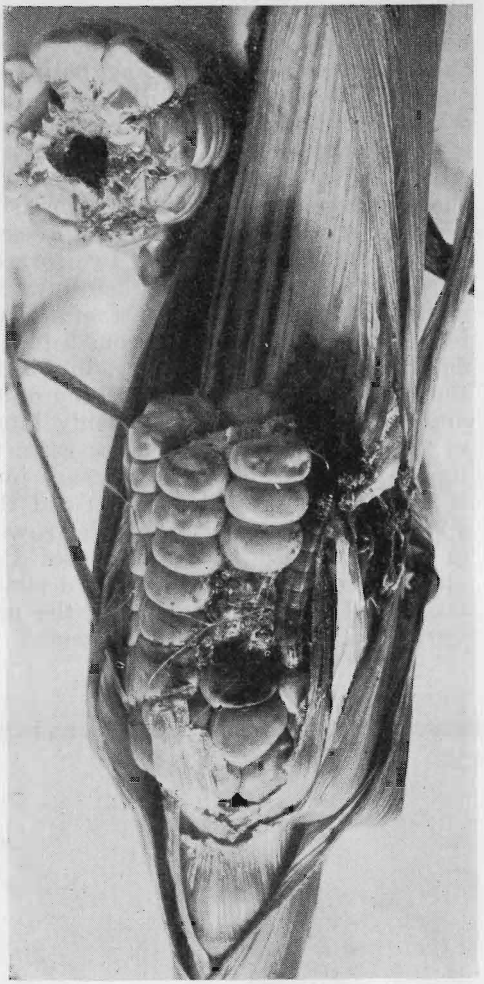

Fig. 6. An ear of corn injured by the stalk borer, *Papaipema nebris* (Gn.).

In the majority of the plants listed as hosts, the larva bores in nearly anywhere along the main stalk or lateral branches and usually extends its burrow in an upward direction. As a rule the damage is soon noticed due to the wilted or broken-down condition of the upper portion of the plant; however, in ragweed, marsh elder, burdock, rhubarb, tobacco and large corn, no evidence of wilting was observed but the presence of the borer was readily detected by the frass and excrement at the base of the plant.

CONFUSION OF INJURY WITH THAT OF OTHER INSECTS

The injuries produced by several other insects, especially some of the more common boring caterpillars, more or less

closely resembles injuries produced by *Papaipema nebris*, and thus in some cases the stalk borer is blamed for depredations of others, and vice versa.

Several other species of the genus *Papaipema* burrow in stems of plants, but, with the exception of *P. purpurifascia* G. & R. working in columbine (*Aquilegia* sp,), *P. furcata* Smith in shoots of ash, *P. humuli* Bird, in hops, *P. cerina* in the Madonna lily (*Lilium superbum* L.) and *P. cataphracta* Grote in various plants, most of these borers attack weeds and wild flowers and are seldom seen in the field. As a rule the species of *Papaipema* are remarkably specific in their host selection. *P. cataphracta*, the one exception (in addition to *P. nebris*) is most likely to be confused with the stalk borer because it attacks many cultivated plants and its injury is not at all unlike that of *P. nebris*. The real test of identity in this case is an examination of the larva itself. In *P. nebris* the longitudinal stripes are interrupted on the first three abdominal segments, whereas in *P. cataphracta* they are continuous.

Two other noctuid borers (*Luperina stipata* Morr. and *Oligia fractilinea* Grote) are often confused with the stalk borer. The four-lined borer (*L. stipata*) may be characterized as working entirely underground. It enters the plant at the crown or just below the surface of the soil and burrows upward into the stalk and in event of the death of the plant it goes down into the soil and then attacks another plant in the same manner. Often all the plants in a hill of corn may be destroyed in this manner without the borer ever appearing above the surface of the ground. The pale yellowish-white larvae which are marked with four broad, reddish-brown, longitudinal stripes, are easily distinguished from those of *P. nebris*. The lined corn borer (*O. fractilinea*) usually ascends the plant and burrows down between the leaves and into the heart of the plant. The larvae are slender, yellowish, reddish-brown, longitudinally striped caterpillars, about 1 inch in length. According to Forbes (13) and Britton (7), the larvae *Oligia Misera* and *Oligia semicana* closely resemble those of *Oligia fractilinea*, and the *injury on* corn is somewhat similar.

The pale western cutworm (*Porosagrotis orthozoma* Morr.), the larva of which is a dull gray or greenish caterpillar is rather inconspisuously marked with fine greenish or greenish brown longitudinal stripes, and it frequently does considerable damage to corn. This species almost invariably attacks the plant below the surface of the soil and burrows upward thru the center of the stalk. When not actually feeding, the larva is usually to be found in the soil a few inches away from the plant. The color pattern of the larva and its characteristic method of attacking the host should render this species easily distinguishable from the stalk borer.

The spindle worm (*Achatodes zeae* Harris) and the hopvine borer (*Hydroecia immanis* Gn.) occasionally injure corn in a manner almost identical to that of *P. nebris*. These borers usually enter near the ground and burrow upward in the stem, but at times they are found working down from above. The larva of the former species is a yellowish-white caterpillar with the head, thoracic and anal shields and the pinacula a glossy black, in strong contrast with the uniform body color. The larvae of the latter species are dirty-white in color and conspicuously marked with irregular rose-colored blotches on each body segment so arranged that they form broken longitudinal stripes.

Wireworms (*Melanotus* spp.) frequently burrow into the side of the stalk and kill the young corn plant.

The armyworm (*Cirphis unipuncta* Haw.), the wheat head armyworm (*Neleucania albilinea* Auct.), the corn ear worm (*Heliothis obsoleta* Fab.), and the cotton cutworm (*Prodenia ornithogalli* Gn.), when feeding on young corn, usually enter the "throat" of the plant and eat large irregular holes in the rolled and unfolding leaves. Upon growing out these leaves present a very ragged appearance.

The sod webworms (*Crambus* spp.) and the bill bugs (*Sphenophorus* spp.) are often responsible for the holes in corn leaves, but as a rule the holes produced by these insects are more or less regular in outline and occur in transverse rows across the blade of the leaf.

In addition to the foregoing insects which attack corn, many other lepidopterous larvae have the habit of boring in the stalks and branches of various cultivated plants and weeds and may at times be mistaken for *P. nebris*. Also there

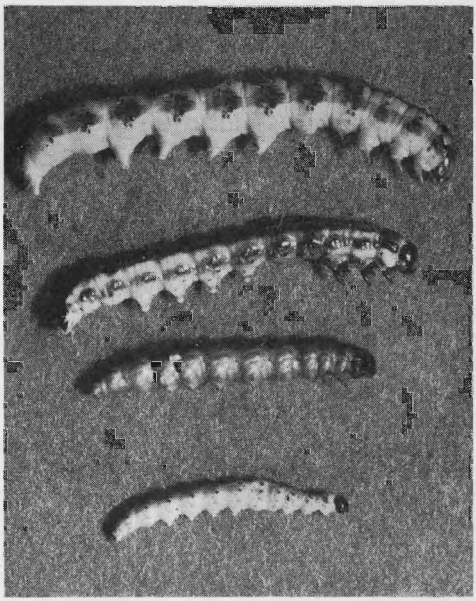

Fig. 7. Caterpillars frequently mistaken for the stalk borer. From top to bottom they are: the corn ear worm (*Heliothis obsoleta* Fab.), the stalk borer *Papaipema nebris* Gn.), the European corn borer *Pyrausta nubilalis* Hubn.), and the smartweed borer (*Pyrausta ainsliei* Heinr.).

are some sucking insects which injure grasses and cereal crops in such a way as to leave dead heads supported by plants that appear healthy. Often this damage is attributed to the activities of young stalk borers.

In most cases where the larvae can be found and compared with the descriptions and illustrations presented in this publication it will be easy to decide whether or not the stalk borer is involved.

SYSTEMATIC HISTORY AND SYNONOMY

The stalk borer was first described by Guenée (17) in 1852 under the name of *Gortyna nebris* and on the same page he described the form *nitela* as a distinct species, *Gortyna nitela*. Almost 30 years later (1878) Riley (30, 34) bred both forms and many intermediate forms from the same material, thus showing that they were varieties of the same species. Due to the confusion that has existed concerning the types and limits of the two genera, *Gortyna* and *Hydroecia*, this species has been frequently changed back and forth from one genus to the other as the types were changed. In 1899 Smith (36), divided the species of *Hydroecia* into two groups using the name *Hydroecia* for one and proposing the name *Papaipema* for the other. These groups were apparently considered by him as subgenera, but later workers have elevated *Papaipema* to full generic rank, and it now stands a valid genus with *P. cerina* Grote as its type.

In some regions the variety *nitela* is more abundant than *nebris* and so the former came to be considered as the typical form and in most of the literature the correct relationship is reversed; i. e., *Nebris* is erroneously considered as a variety of *nitela*. Several writers have recognized that *nebris* had priority over *Nitela*, but for one reason or another they continued to use the latter name. The most recent workers, however, have been using the correct name, *P. nebris*.

PRESENT SYNONOMY

1852 *Gortyna nebris* Guenée. Spec. Gen. des Lepid. 5, 124.
1852 *Gortyna nitela* Guenée. Spec. Gen. des Lepid. 5, 124.
1867 *Gortyna nitela* Riley, C. V. Prairie Farmer, Vol. 19, Feb. 23.
1881 *Gortyna nitela* Riley, Papilio, Vol. 1, p. 106.
1882 *Gortyna nitela* Lintner, 1st Rept. N. Y. Ent. p. 110
1893 *Hydroecia nitela* Smith, Bul. 44, U. S. N. Mus. p. 178.
1898 *Hydroecia nitela* Bird, Can, Ent. XXX, p. 127.
1899 *Papaipema nitela* Smith, Trans. Amer. Ent. Soc. Vol. 26, p. 34.
1901 *Gortyna nebris* Lyman, Canadian Ent. p. 317.
1902 *Papaipema nitela* Dyar, U. S. Nat'l. Mus. Bul. 52, p. 124.

1908 *Papaipema nitela* Washburn, 12th Rept. State Ent. of Minn. p. 151.
1910 *Papaipema nebris* Hampson, Cat. Lepid. Phal. Vol. 9, p. 85.
1917 *Papaipema nebris* Barnes & McDunnough, Cat. Lepid. N. A. p. 69.
1921 *Papaipema nebris* Bird, Can. Ent. Vol. 53, p. 79.
1927 *Papaipema nebris* Lowry, N. H. Ag. Exp. Sta. Tech. Bul. 34 p. 8.

COMMON NAMES

Many common names have been applied to this species and most of them are based on the larvel habit of boring into its hosts. It is variously referred to as the "heart worm", the "common stalk borer", the "potato stalk borer", the "dahlia borer", etc. "The Stalk Borer", however, has been adopted as the approved name by the American Association of Economic Entomologists. To the farmer the larvae are known as "worms" or "borers."

ORIGINAL DESCRIPTIONS

194. *Gortyna Nebris* Gn.

Taille des deux sexes; 38 mm. Ailes supér. tres-entieres, d'un brun de bois clair, avec la ligne coudée seule distincte, d'un blanc-jaunatre plus ou moins éteint. Les trois premieres taches blanches, comme dans les especes précédentes, l'intermédiaire souvent jaune. Reniforme composeé d'une tache centrale plus grande, ordinairement jaune, et de cinq ou six autres tréspetites, punctiformes, qui l'entourent. Ailes infér. d'un brun cendré, uni dans les deux sexes. Thorax et abdomen cendrés. Abdomen long. Base des antennes blanche.

Male plus petit, tout l'espace terminal et subterminal plus clair. Ailes infer. plus pales.

Amerique Septentrionale, Etat des Illinois. Coll. Bdv. et Dbday.

195. *Gortyna nitela* Gn.

Taille et couleur de la Nebris, dont elle ne differe que par l'absence complete des taches blanches, et les palpes un peu plus longs et plus ascendants. Ailes-superieures d'un brun cendré clair, semé d'atomes fins jaunatres. Ligne coudée seule distincte, d'un blanc-jaunatre; derriere elle le fond devient plus clair, puis il reprend son ton general en approchant du bord terminal. Aucune tache. On voit seulement, et surtout quand on regarde l'insecte en transparence, deux groupes d'ecailles plus sombres et comme plus serrées, a la place des deux taches ordinaires. Ailes infer. d'un gris-livide uni, avec une lunule cellulaire de part et d'autre.

Etat des Illinois. Coll. Doubleday. Un seul male.

Plus petite. Des traces d'une subterminale composee de points jaunatres, ombres antérleuerement de foncé.

Etat de New York. Coll. Doubleday. Un seul male.

DESCRIPTIONS

EGG

Globular to oblate-spheroidal, somewhat flattened, circular in cross section, quadrate in vertical section, pearly white when first laid but soon changing to brownish gray or amber; micropile on slight elevation in center of one flattened pole, surrounded by a rosette of pyriform cells; exochorion sculptured with approximately 50 raised longitudinal ridges and many small cross ridges forming numerous shallow pits, quadrangular in equatorial region and irregular polygonal and trapezoidal near the poles.

Equatorial diameter 0.595 mm. Polar diameter .444 mm.

LARVA

PENULTIMATE AND EARLIER INSTARS

Head rounded, circular to obovate in outline, dark brown to black in first and second instars, yellowish in third and subsequent instars; smoky line extending from trophi to occiput after third instar; trophi and occeli inconspicuous, largely obscured by the dark lateral band. Body moderately slender, sylindrical tapering towards both extremities; without secondary hairs. Thoracic shield broad fuscous in early instars; lemon yellow to amber with fuscous lateral stripes in later instars. Anal shield fuscous in early instars, yellow to amber with fuscous stripe along lateral and caudal margins. Legs and prolegs normal in late instars; prolegs on third and fourth abdominal segments shorter than those on fifth and sixth abdominal segments in early instars. (This causes small larvae to move with a looping movement similar to that of genmetrid larvae). Characteristic color pattern evident in all instars; ground color dirty white to flesh color; brownish purple markings on body segments (described in next section for last instar larva.

Head capsule measurements for each instar are given in table I.

LAST INSTAR LARVA

Head light chestnut brown in color with a dark brown or blackish lateral stripe from hind margin forward to include ocelli; trophi dark or blackish; ocelli, six on each side, yellow, approximately equal in size.

TABLE I. LARVAL HEAD CAPSULE WIDTHS IN MM.

Number of instars		Instar										Index of growth
		1	2	3	4	5	6	7	8	9	10	
	Theoretical	.252	.380	.573	.866	1.31	1.97	2.98				151
7	Actual	.252	.378	.572	.867	1.33	2.04	2.91				
	Theoretical	.252	.360	.514	.736	1.05	1.50	2.15	3.07			143
8	Actual	.252	.356	.513	.738	1.09	1.56	2.19	2.99			
	Theoretical	.252	.340	.459	.619	0.84	1.12	1.52	2.06	2.98		135
9	Actual	.252	.342	.461	.623	0.87	1.17	1.56	2.08	2.95		
	Theoretical	.252	.330	.432	.566	0.74	0.97	1.27	1.66	2.17	2.84	131
10	Actual	.252	.330	.433	.569	0.76	1.01	1.32	1.72	2.21	2.86	

Epistoma with normal setae (E^1,E^2); the distance between E^2 on each side more than twice the distance between E^1 and E^2. Frontal punctures (F^a) close together, between and slightly anterior of frontal seta (F^1), near lower margin of frons. Adf^1 equidistant from F^1 and Adf^2; Adf^2 well behind beginning of LR; Frontal puncture (Adf^a; anterior to beginning of LR equidistant between Adf^1 and approximately in line with F^1 and Adf^2. Anterior setae (A^1, A^2 and A^3) forming an obtuse angle; A^2 short, about equidistant from A^1 and A^3; A^1 and A^3 long. Anterior puncture (A^a) equidistant from, and above a line connecting A^2 and A^3. Posterior setae (P^1, P^2) long, P^1 laterad and slightly posterior of Adf^2; P^2 posterior and slightly laterad of P^1; the distance between P^1 and P^2 equal to the distance between P^1 and Adf^2. Posterior punctures two; P^a nearer to L^1 than to any other setae; lying between L^1 and Adf^2; P^b close to and slightly anterior of P^2. Lateral seta (L^1) remote from P^1 and A^3 with which it forms a right triangle, L^1 P^1 being perpendicular to L^1 A^3. Lateral puncture (L^a) remote, postero-ventrad of ocellus VI. Ocellar puncture (O^a) lying between ranged in the form of an equilateral triangle; O^1 directly ventrad of ocellus IV; O^2 postero-ventrad of ocellus I; O^3 remote, postero-ventrad of ocellus VI. Ocellus puncture (O^a) lying between O^3 and ocellus VI but nearer to the ocellus than to the setae. Genal seta (G^1) remote, postero-ventrad of O^3. Genal puncture (G^a) antero-dorsad of G^1. Subocellar setae (SO^1, SO^2, SO^3) triangularly placed, SO^2 very close to ocellus V. Subocellar puncture (SO^a) equidistant from and slightly below a line connecting SO^2 and SO^3 (fig. 8).

Body cylindrical: moderately stout; tapering towards both extremities; without secondary hairs; mostly dirty white or flesh color, with a band of purplish brown around the metathoracic and the first 3 abdominal segments, a subdorsal and a

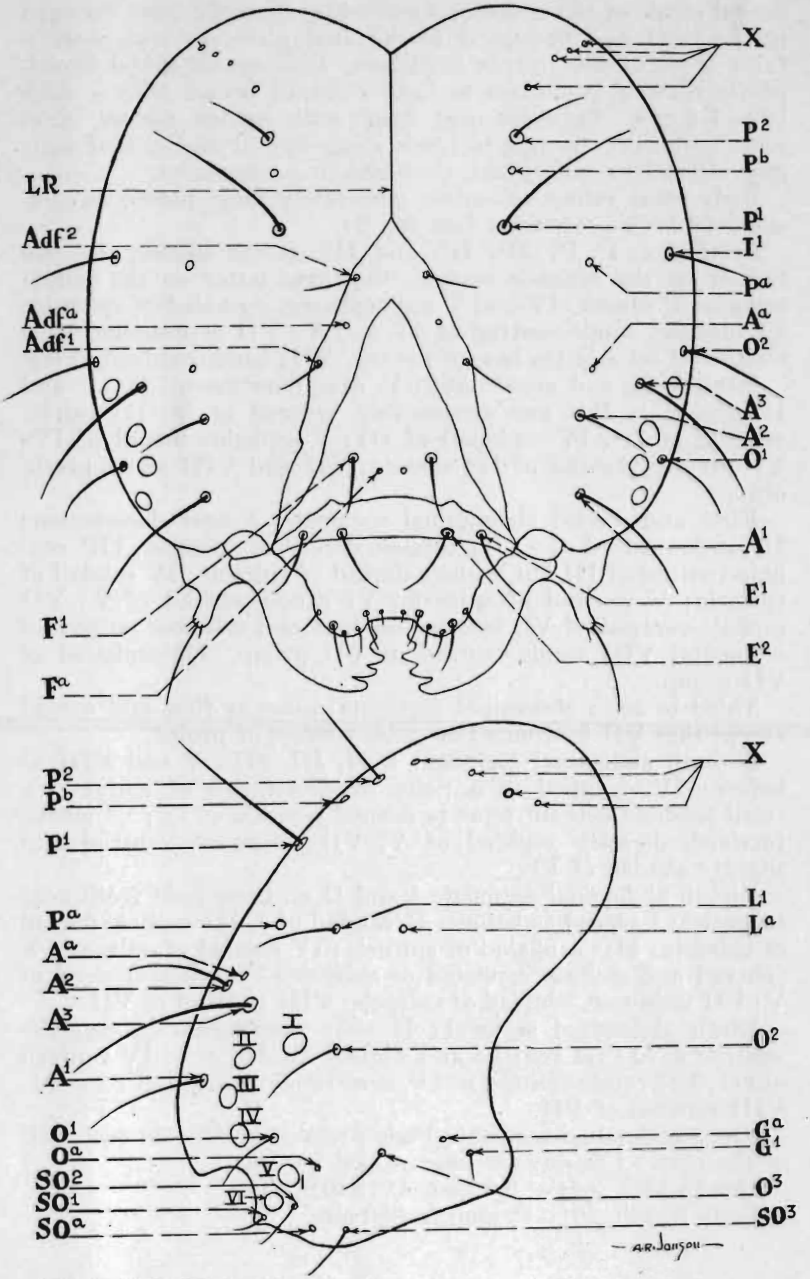

Fig. 8. Head capsule of a mature larva showing setal arrangement—above, dorsal view; below, lateral view.

lateral stripe of the same color extending from the band forward to the head and backward to the anal plate, or with only a faint trace of the purple markings. Prothoracic shield broad, partly divided, yellowish to light chestnut brown with a dark lateral stripe. Spiracles oval, black with lighter centers. Anal plate yellowish, fuscous to black along lateral and caudal margins. Crotchets uniordinal, arranged in a mesoseries.

Body setae yellow to amber, moderately long, placed on conspicuous brown tubercles (see fig. 9).

Prothorax: I^a, I^b, II^a, II^b, and II^c on the shield; the two former on the cephalic margin, the three latter on the caudal margin; I^c absent, IV and V approximate, cephalad of spiracle; VI bisetose, caudo-ventrad of IV and V; VII represented by a number of setae at the base of the leg. VIII caudo-ventrad of leg.

Mesothorax and metathorax: I^a near dorsomeson, I^b, II^a and II^b almost in line and successively ventrad of I^a; III caudo-ventrad of II^b; IV cephalad of III; V cephalo-ventrad of IV; VI directly ventrad of II^b, remote; VII and VIII as on prothorax.

First and second abdonminal segments: I near dorsomeson; II caudo-ventrad of I; III cephalo-dorsad of spiracle; III^a cephalo-ventrad of III but cephalo-dorsad of spiracle; IV caudad of spiracle; V ventrad of spiracle; VI caudo-ventrad of V; VII cephalo-ventrad of VI, bisetose on first and trisetose on second segments; VIII caudo-ventrad of VII group. IX cephalad of VII group.

Third to sixth abdominal segments; same as first and second except that VII is situated on outer surface of proleg.

Seventh abdominal segment; I, II, III, III^a, V and VIII as before; IV dropped to a point caudo-ventrad of spiracle; a small tubercle without setae in normal position of IV; VI moved forward, directly ventrad of V, VII unisetose, ventrad and slightly caudad of VI.

Eighth abdominal segment: I and II on prominent rectilinear tubercles; I placed as before; II caudad of I, III cephalo-dorsad of spiracle; III^a caphalad of spiracle; IV caudad of spiracle; V ventrad and slightly cephalad of spiracle; VI caudo-ventrad of V; VII unisetose, ventrad of spiracle; VIII ventrad of VII.

Ninth abdominal segment: II near dorsomeson: I cephalo-ventrad of II: III ventrad and slightly caudad of I; IV ventrad of III; VII caudo-ventrad of IV, near caudal margin of segment; VIII ventrad of VII.

Tenth abdominal segment: Four prominent setae on each half of the plate; five setae at base of each proleg.

Head width, 2.64 — 3.3 mm. Av. 2.912 mm.

Body length, 26 — 32 mm. Av. 30 mm.

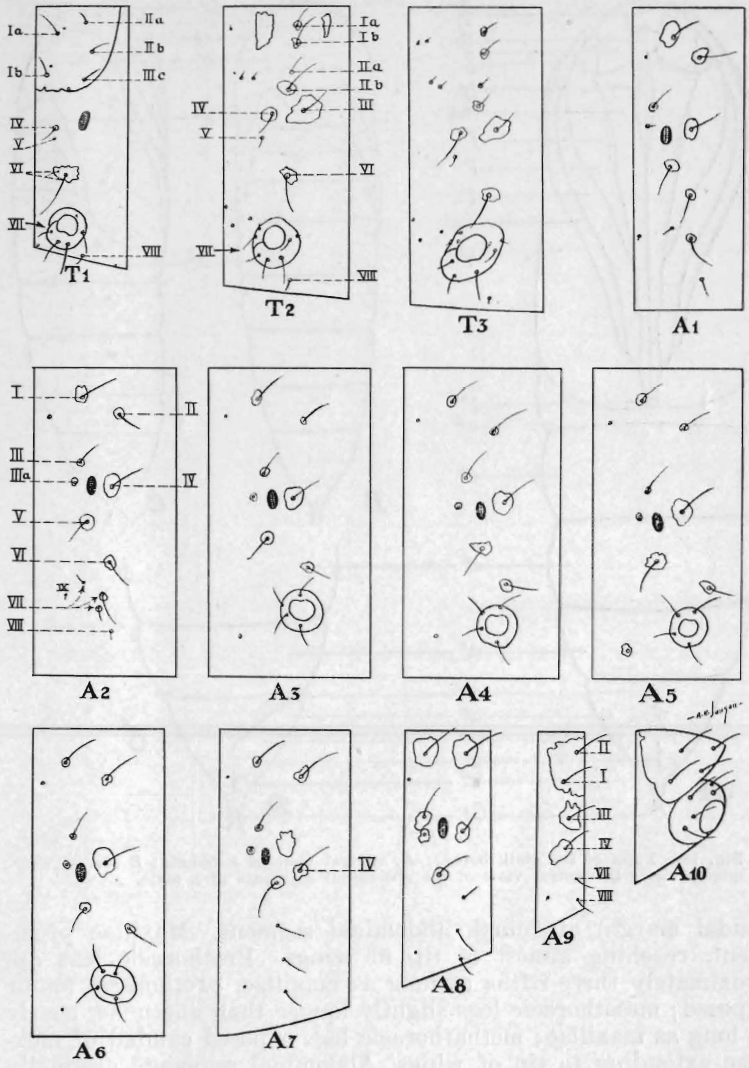

Fig. 9. Setal pattern of a mature larva of *Papaipema nebris* (Gn.).

PUPA

Typical noctuid pupa; (fig. 10) labrum separated from clypeus by distinct suture, labial palpi visible, about one-fifth length of maxillae; mesothoracic wings reaching nearly to ventro-

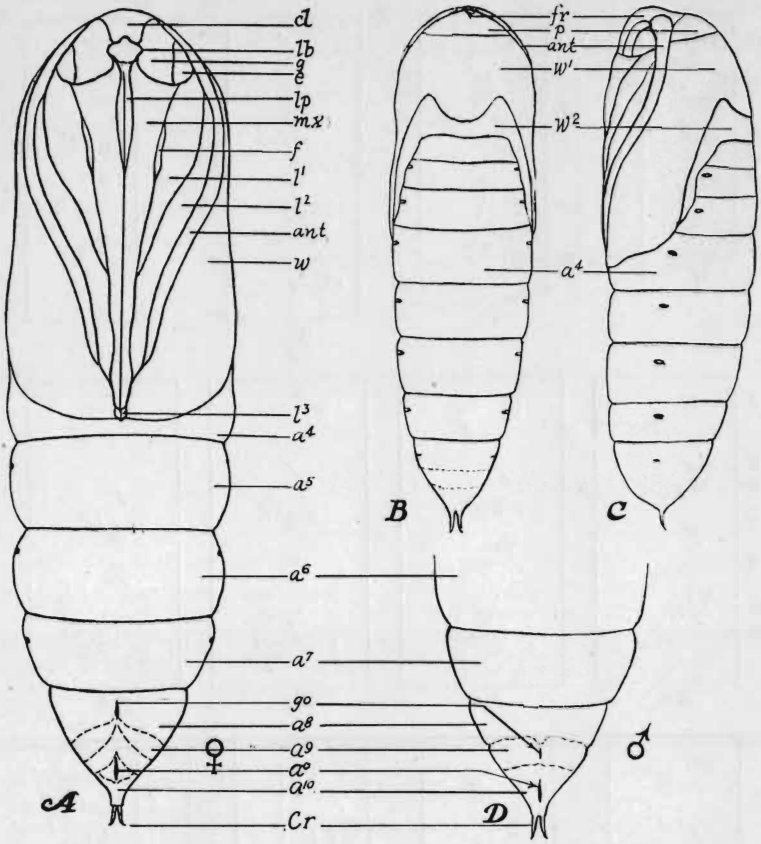

Fig. 10. Pupa of the stalk borer: A, ventral view of a female; B, dorsal view; C, lateral view; D, ventral view of the abdominal segments of a male.

caudal margin of fourth abdominal segment. Maxillae prominent, reaching almost to tip of wings. Prothoracic legs approximately three-fifths as long as maxillae, prothoracic femur exposed; mesothoracic legs slightly longer than antennae, nearly as long as maxillae; methathoracic legs exposed caudad of maxillae extending to tip of wings. Abdominal segments gradually tapering; dorsocephalic margins of abdominal segments three, four, five, six and seven strongly punctate, pit markings extending around to ventral surface of segments five, six and seven, caudal margins of segments five, six and seven minutely punctate. Spiracles (except eighth abdominal) ellipsoidal, dark brown; eighth abdominal spiracle reduced to slit-like opening. Proleg scars absent, larval setae and setal arrangement of ab-

dominal segments largely retained. Cremaster short, somewhat flattened dorso-ventrally, terminating in two short, slender, divergent, slightly curved spines. Color varying from light to dark brown (according to age.) Genital opening of female simple, slit-like cephalad of eighth abdominal spiracle, cephalic margins of ninth and tenth abdominal segments curved forward towards genital opening; genital opening of male simple, slit-like, on slight elevation caudal of eighth abdominal spiracle, on ventro-caudal margin of ninth abdominal segment.

Length 16-22 mm. Greatest width 5-7 mm.

ADULT

Ground color reddish-brown, the scales more or less tipped with grey or white to produce mouse or fawn grey color. Head smooth on frons, antennae simple (minutely ciliated) pale yellowish brown, lighter near base, set in tuft of white tipped scales; tarsi ringed with white. Fore wings varying shades of brown (olivaceous, reddish, purplish) sprinkled with grey. Base line barely distinguished; antemedial line more or less indistinct, whitish defined with brown on outer margin, irregular and strongly out-curved at margin; post medial line distinct, white or yellowish, defined on inner margin and sometimes on outer margin by brown, strongly excurved from costa around reniform, then inwardly olique to hind margin; post medial space darker than antemedial and terminal spaces; subterminal line variable in distinctiveness, dentate, yellow, or white, defined on inner margin by brown (may be represented by light spots, dashes or wanting); sub-terminal space very light along post median line and fading out towards sub-terminal; terminal line poorly defined; cilia and fringe scales brown, pale at base and tips. Ordinarily spots variable in distinctiveness; claviform divided into

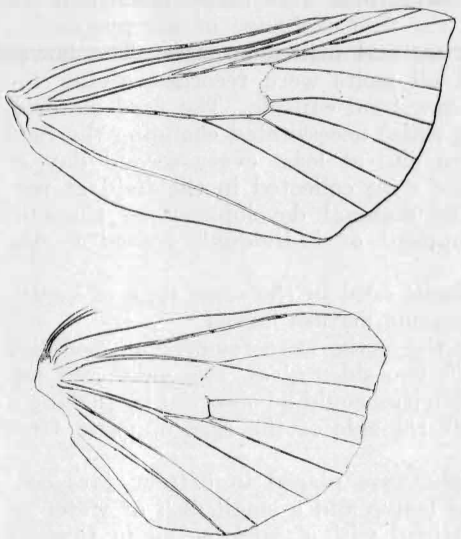

Fig. 11. Fore and hind wing of adult, showing wing venation.

two small white spots; orbicular small, irregular and white; reniform with central lunule yellow, partly surrounded by small white spots, one to three above and three below. Five small white spots on costa beginning near reniform; other white spots on outer margin at terminus of principal veins. Hind wing pale grayish brown to smoky above, fawn grey below mixed with brown along costa and terminal margin. Abdomen uniform fawn grey, with dorsal crests on basal segments.

Expanse 25-40 mm.

Var. nitela. Fore wing with the spots (claviform, orbicular, reniform) obscure or represented by indistinct smoky areas.

METHODS

Practically all of the experiments were performed in the screened out-door laboratory of the Insectary at Iowa State College. The controlled temperature experiments were conducted in incubators which held constant to within one-tenth degree centigrade.

The life history data were secured by rearing individual larvae in shell vials and stender dishes. Small shell vials (13 mm. x 60 mm.) were used for the first four instars, and (60 x 35 mm.) stender dishes or 3-ounce crystal glass ointment jars, were used for the latter instars. The 3-ounce ointment jars with perforated aluminum tops were found to be most satisfactory for work with the larger caterpillars. Observations were easily made and the perforated lids permitted the free exchange of air preventing the accumulation of moisture and injurious gases. The larvae were examined daily and all molts were recorded giving the width of the old and the new head capsule. The food material was kept fresh at all times which necessitated changing the food daily at high temperatures and at least every second day at lower temperatures. Larvae were collected in the field at regular intervals to check the seasonal development of those in the field with the development of individuals reared in the Insectary.

Pupae were placed on moist sand in the same type of ventilated jar as was used for rearing mature larvae.

Shortly after emergence the moths were removed to modified Riley cages (1′ x 1′ x 2″, two sides glass, two sides and top cheesecloth) where their activities could be observed by placing a red electric light bulb near the side of the cage opposite from the observer.

Individual pairs of moths were placed in battery jars containing dead corn or grass leaves and a small dish of water or dilute honey solution provided with a wick so as to prevent drowning of the moths. These cages were examined daily and all eggs were counted and removed. Other pairs caged with

both dead and living plants were left undisturbed until after the death of the moths when the full complement of eggs was counted.

In most cases the eggs were left attached to the plants on which they were deposited and were kept in the outdoor laboratory during the winter.

SEASONAL HISTORY AND HABITS

EGG

The eggs, which are deposited singly or in masses (of from 2 to 100) on the leaves and stems of dead grasses and weeds, are most frequently placed well down between the leaf sheath and the main stem, in rolled and folded leaves or in cracks and crevices of the main stem (see fig. 12). The time, place and method of deposition is discussed eleswhere in this bulletin.

The length of the egg stage varies from about 7½ to 8½ months. Eggs deposited between Aug. 15 and Oct. 1 hatch during the first two weeks of the following May. Altho the majority of the eggs normally hatch during the fore part of May, extreme variations in soil type and topography as well as variations in the amount of protection offered by shade, leaf mulch and snow so affect the temperature that hatching is actually prolonged for four or five weeks. In 1927 eggs on a sandy south slope hatched April 30, whereas eggs on a shaded north slope, where the snow remained until very late in the spring, did not hatch until June 1. Similar variations were observed in other years.

The date of hatching, altho influenced to some degree by the factors just mentioned, is largely determined by the pre-

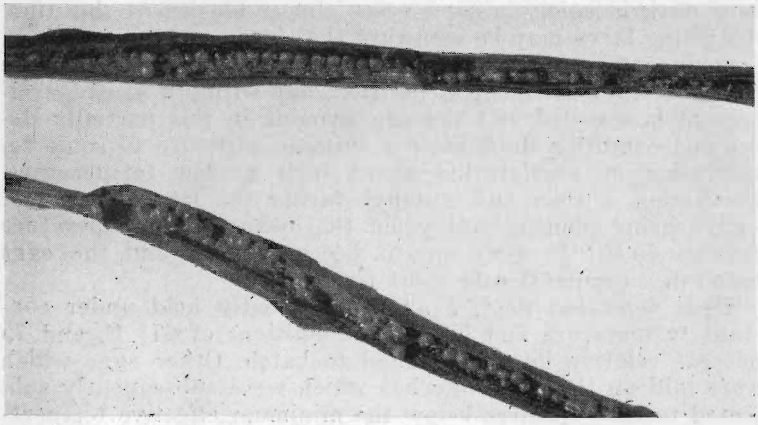

Fig. 12. Eggs of the stalk borer in rolled grass leaves.

vailing temperatures during February, March and April, especially April. Temperatures below normal for March and April of 1926 and April of 1928 resulted in unusually late hatching of *Papaipema* eggs. Hatching dates for the five-year period (1926-1930) are given in table II. It may be noted that the earliest hatching date recorded was April 19 (1930), the latest was June 5 (1928) and that the peak usually occured between May 1 and May 15.

TABLE II. HATCHING DATES

Year	Earliest date	Peak	Last date
1926		May 15-20	
1927	Apr. 30	May 5-10	June 1
1928	May 4	May 10-15	June 5
1929	Apr. 26	May 1-10	May 30
1930	Apr. 19	Apr. 25-30	May 17

The date of egg deposition in no way affected the time of hatching. In many cases the first and the last laid eggs hatched on the same day.

DEVELOPMENT

Certain changes in the external appearance of the egg accompany development. The original pearly white color of the egg lasts but a few hours. In from 24 to 48 hours the egg changes to a uniform brownish-gray or amber and remains practically unchanged until from two to ten days before hatching, depending upon the temperature, when they become very dark in color, in some cases almost black. At this time the young larva may be seen thru the chorion of the egg.

Some embryological development takes place during the first few days after egg deposition, but within a week development is arrested and the egg remains in this partially developed condition until after a suitable exposure to some reactivating or accelerating agent such as low temperature. Incubation is slow and gradual during the late winter and early spring months, but when the mean daily temperature reaches 45-50° F. development becomes rapid and the eggs hatch in a comparatively short time.

Eggs deposited Sept. 1 and subsequently held under constant temperature and humidity conditions of 27° C. and 75 percent relative humidity failed to hatch. Other eggs which were laid on the same day but which were subsequently subjected to temperatures below the minimum effective temperature (5, 0 and —5°, respectively) for one month or longer de-

veloped normally when replaced under conditions favorable for incubation. Still other eggs which were laid on the same day were left out of doors and at two week intervals samples were brought in and incubated under favorable conditions (27° C. and 75 percent relative humidity). Samples brought in after Dec. 1 hatched normally and each succeeding lot had a slightly shorter incubation period. A fourth lot of eggs which was held at the high temperature until Jan. 15, then subjected to out of door conditions for one month and returned to favorable conditions hatched normally. Under such conditions of manipulated temperature the egg stage can be reduced from approximately eight months to two months.

Low relative humidities have a slight retarding effect on development, but are comparatively unimportant in determining the duration of the egg stage. Prolonged exposure to an atmosphere of less than 50 percent relative humidity at temperatures above 20° C. results in the dehydration and shriveling of the egg, but these conditions seldom occur between Sept. and May, and, consequently, few eggs except infertile ones are destroyed in this way. Low relative humidities are most harmful to the egg when they occur near the end of the incubation period. At this time they have a marked retarding effect and materially delay hatching. Under such conditions many eggs have been observed in which completely developed larvae had died.

LARVA

FIRST APPEARANCE

Newly hatched larvae appear during late April or early May and begin at once to feed upon young grass and weeds. Altho eggs normally hatch between daybreak and noon, many were observed to hatch later in the day. Larvae hatching on hot, bright days frequently remained hidden until evening, while on cool, cloudy days they went about their business of locating a host plant the same as at night. Except for a few cases in which the larvae ate part of the shells from which they emerged or portions of dead leaves and stems, they did not feed until they found fresh green plants.

FEEDING HABITS

In seedling weeds the newly hatched larvae usually appear as miners in the cotyledons or leaves of the plant, whereas in grasses they usually work directly into the main stem. Upon the death of the initial host the larva migrates to another plant where it burrows into the main stalk.

Early in the season when the weeds are from 3 to 8 or 10 inches tall the borers almost invariably enter the plant at or

just above the surface of the soil, but later when the plants are larger the larvae bore in anywhere between the base and the tip of the plant. As a rule the burrows proceed upward from the point of entrance, but in some instances they extend both above and below the entrance. The borers keep their feeding burrows comparatively clean by ejecting most of the ecrement and frass thru the entrance hole at the bottom of the burrow.

Grasses and most small-stemmed plants seldom contain more than one borer per plant, but a large branching weed, e. g., a large plant of giant ragweed (*Ambrosia trifida*), may contain 30 or more borers. In this case the borers are in usually separate burrows, and it is very exceptional to find two or more borers in a single burrow.

LARVAL MIGRATION

Whenever the plant in which a borer is working dies or is cut off or when the larva has grown so large that the old stem will not accomodate it, the larva is forced to migrate to a new plant, and usually it is required to make a selection from several available plants. The selection of the new host plant is largely a matter of chance. The larva wanders about more or less aimlessly until it encounters an upright object and then regardless of whether the object is a stick, dead plant or a suitable host plant

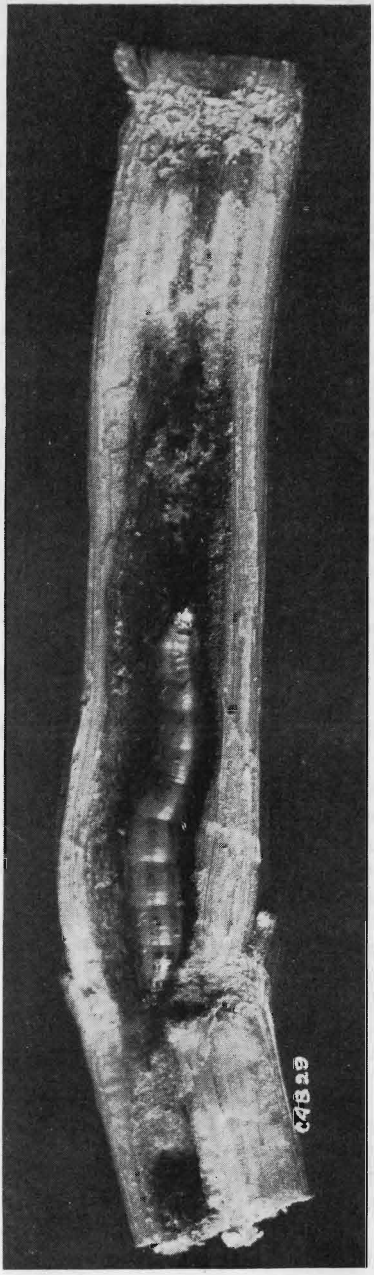

Fig. 13. Larva of the stalk borer in a cornstalk.

the borer climbs to the top and examines it thoroly. In case the object does not prove to be a desirable host plant the borer descends to the ground and starts out as before. Apparently the borers are not aided by sight or scent until they are very close to a plant. Migrating caterpillars have frequently been observed to pass within a few inches of a very desirable corn or ragweed plant and then encounter an upright stick which they would examine minutely before moving on to find a plant.

TROPISMS

Newly hatched larvae react positively to light and negatively to the force of gravity, the former being the dominant reaction in cases where the two are opposed. Larvae placed in a cylindrical glass jar will collect at the top and on the side nearest the light. If the upper portion of the cylinder is covered with a larger opaque cylinder, the larvae will collect on the light side of the crystalline jar and at the lower margin of the opaque cylinder. In older larvae these reactions are not so noticeable, and at the time the larvae are preparing for pupation they are practically reversed.

CANNIBALISM

The stalk borer larvae are so given to cannibalistic tendencies that it is impossible to rear them gregariously. They are so vicious and irritable that a chance meeting of two borers always results in a fight. As a rule the larger and more powerful contestant wins, but often the contest is not settled until both have been mortally wounded.

In addition to killing and occasionally eating larvae of their own species, the borers sometimes feed upon other insects. On one occasion a half grown larva which was about to tunnel into a ragweed plant stopped to examine the burrow of a smaller borer (*Epiblema scudderiana* Clem.), and when the occupant came to defend its burrow it was dragged out and destroyed by the stalk borer.

ECDYSIS

A few hours before molting the larva stops feeding and becomes quiet and motionless. Gradually the body assumes a swollen appearance, with an especially prominent white swollen area appearing between the head and the prothoracic shield. As time passes the body begins to contract spasmodically until finally the cuticula ruptures back of the head, setting it free from the rest of the old skin, which is gradually worked back over the body. Then the old head capsule is quickly removed by rubbing it against the wall of the burrow.

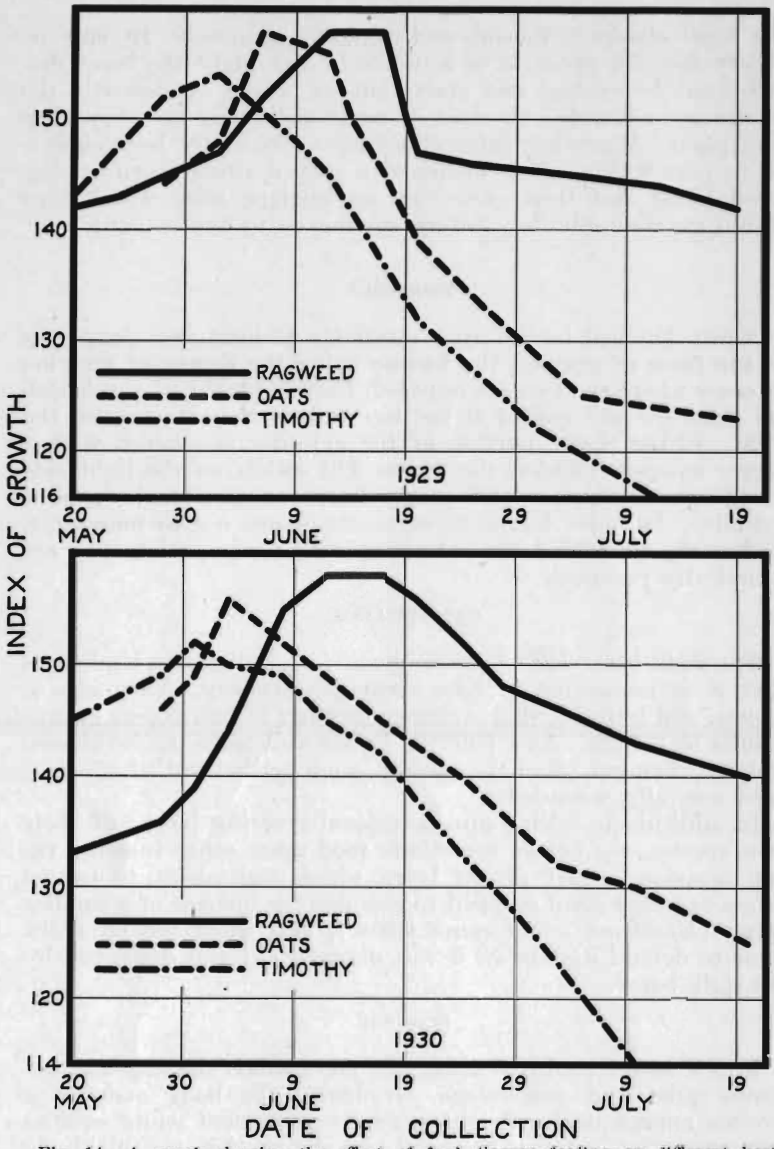

Fig. 14. A graph showing the effect of food (larvae feeding on different host plants) upon the index of growth.

INSTARS

The number of larval instars varies from seven to sixteen. Most of the borers complete development in from seven to nine instars, and individuals having more than 12 instars are rather

rare. When the larvae are supplied with an abundance of good succulent food they normally complete development in seven or eight instars and the growth curve is comparatively smooth, but when food is of poor quality (hard, dry, sour or moldy) the rate of growth is reduced. Molting continues at regular intervals, but the successive instars show little or no increase in size.

There is a marked tendency toward a sexual difference in the number of molts. In many cases the males complete development with one less molt than do females.

DURATION OF STADIA AND LENGTH OF LARVAL LIFE

The length of each individual stadium depends primarily upon the temperature whereas food and other conditions are of secondary importance. At relatively high temperatures larvae are very active; they feed voraciously and grow rapidly but when the temperature drops their activity and growth are retarded. Larvae reared at 30° C. developed approximately three times as fast as those reared at 20° C.

When *Papaipema nebris* larvae are reared at a constant temperature the second stadium is shorter than the first and the stadia after the second becomes successively longer up to the seventh, which is the longest, except in individuals having more than seven molts. In those cases the seventh stadium is shortened and the last stadium becomes the longest (see table III).

TABLE III. DEVELOPMENT OF LARVAE REARED AT 27° C.

No. of molts to complete development	Number of days in each stadium										Total av.
	I	II	III	IV	V	VI	VII	VIII	IX	X	
7	4	3.6	3.7	4.5	10	15	28				68
8	4	3.5	3.8	4.4	5.6	7.1	13.8	28			71
9	4	3.4	3.9	4.2	5.3	6.2	9.0	14.1	26		76
10	4	3.5	3.7	4.1	5.2	6.1	7.2	8.5	13.6	24	80

Larvae reared in the screened laboratory under normal outdoor temperature conditions give comparable results except that the first and second stadia may be considerably lengthened by the low spring temperatures, and there may be some irregularities in the comparative length of later stadia due to variations in the comparative length of later stadia due to variations in prevailing temperatures (see tables IV, V, VI and VII). The tables do not show these variations in their extreme because of the moderating influence produced by running more than one series of slightly different aged larvae each year.

Since food conditions determine the amount of growth that takes place during a stadium or during any given interval of time (see fig. 15), it is evident that these conditions may mater-

TABLE IV. DEVELOPMENT OF SEVEN INSTAR LARVAE IN SCREENED INSECTARY

1926	Number of days in each stadium						
	I	II	III	IV	V	VI	VII
Minimum	8	4	3	4	6	7	18
Maximum	14	7	9	10	12	14	27
Average	11.3	5.5	6.4	7.7	9.3	11.1	23.6
Specimens	4	4	4	4	4	4	4
1927							
Minimum	8	3	4	5	5	9	20
Maximum	16	3	9	12	13	16	41
Average	12.4	5.8	7.5	8.3	8.8	13.3	25.3
Specimens	7	7	7	7	7	7	7
1928							
Minimum	7	3	3	4	5	7	19
Maximum	12	9	9	11	11	21	31
Average	9.7	6.0	6.7	7.4	8.5	11.4	26.5
Specimens	19	19	19	19	19	19	19
1929							
Minimum	10	4	3	4	4	8	18
Maximum	17	10	9	11	12	14	29
Average	14.3	7.2	6.1	8.8	8.4	11.0	24.5
Specimens	6	6	6	6	6	6	6

TABLE V. DEVELOPMENT OF EIGHT INSTAR LARVAE IN SCREENED INSECTARY

1926	Number of days in each stadium							
	I	II	III	IV	V	VI	VII	VIII
Minimum	8	3	3	4	6	6	6	17
Maximum	14	8	9	10	12	13	15	26
Average	11.1	5.4	6.2	7.7	9.0	9.7	10.2	21.2
Specimens	10	10	10	10	10	10	10	10
1927								
Minimum	9	3	4	5	6	7	7	17
Maximum	16	9	9	11	11	13	13	37
Average	12.2	5.7	7.1	8.4	8.8	10.4	9.9	22.9
Specimens	17	17	17	17	17	17	17	17
1928								
Minimum	7	3	4	5	6	6	7	18
Maximum	13	8	9	9	11	12	13	39
Average	9.8	5.6	6.5	7.3	8.7	9.3	10.0	24.5
Specimens	28	28	28	28	28	28	28	28
1929								
Minimum	11	4	3	4	5	6	6	17
Maximum	16	9	9	11	11	12	13	29
Average	13.9	7.4	6.3	8.3	8.6	9.1	9.8	22.7
Specimens	13	13	13	13	13	13	13	13

TABLE VI. DEVELOPMENT OF NINE INSTAR LARVAE IN SCREENED INSECTARY

1926	Number of days in each stdium								
	I	II	III	IV	V	VI	VII	VIII	IX
Minimum	10	3	3	4	6	7	6	7	17
Maximum	15	7	8	9	12	13	13	13	27
Average	12	5.2	6.0	7.4	9.0	9.1	9.4	10	20
Specimens	7	7	7	7	7	7	7	7	7
1927									
Minimum	9	3	4	5	6	5	6	6	17
Maximum	14	8	9	11	11	13	13	14	26
Average	11.9	5.5	7.1	8.2	8.2	8.9	9.1	9.8	21.1
Specimens	13	13	13	13	13	13	13	13	13
1928									
Minimum	8	4	3	3	5	6	7	7	18
Maximum	12	8	9	10	12	12	13	17	29
Average	9.6	6.1	6.2	7.3	8.0	8.7	9.3	10.2	22.5
Specimens	20	20	20	20	20	20	20	20	20
1929									
Minimum	10	4	4	5	5	5	6	6	18
Maximum	16	9	8	10	12	16	13	14	36
Average	13.8	7.3	6.4	7.1	8.2	8.5	9.0	9.5	21.3
Specimens	11	11	11	11	11	11	11	11	11

TABLE VII. DEVELOPMENT OF TEN INSTAR LARVAE IN SCREENED INSECTARY

1926	Number of days in each stadium									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Minimum	9	3	3	4	5	5	6	7	6	16
Maximum	14	7	8	9	12	12	13	15	16	27
Average	11.2	5.4	6.2	7.6	8.4	8.5	9.0	9.6	9.9	18.5
Specimens	5	5	5	5	5	5	5	5	5	5
1927										
Minimum	9	3	4	4	5	6	5	6	6	17
Maximum	16	8	9	11	12	11	13	13	14	31
Average	12.5	5.5	7.4	8.3	8.0	8.4	8.2	9.3	9.8	20
Specimens	20	20	20	20	20	20	20	20	20	20
1928										
Minimum	8	4	3	4	5	5	6	6	7	17
Maximum	13	8	9	9	11	12	13	13	15	29
Average	9.7	5.9	6.6	7.0	7.9	8.4	8.5	8.9	10	21.4
Specimens	12	12	12	12	12	12	12	12	12	12
1929										
Minimum	9	4	3	4	5	5	5	6	7	16
Maximum	16	9	9	10	10	11	11	13	13	34
Average	14.3	7.0	6.1	8.2	7.9	8.4	8.4	9.0	9.3	20.1
Specimens	6	6	6	6	6	6	6	6	6	6

ially influence the length of larval life by increasing or decreasing the number of molts required to complete development.

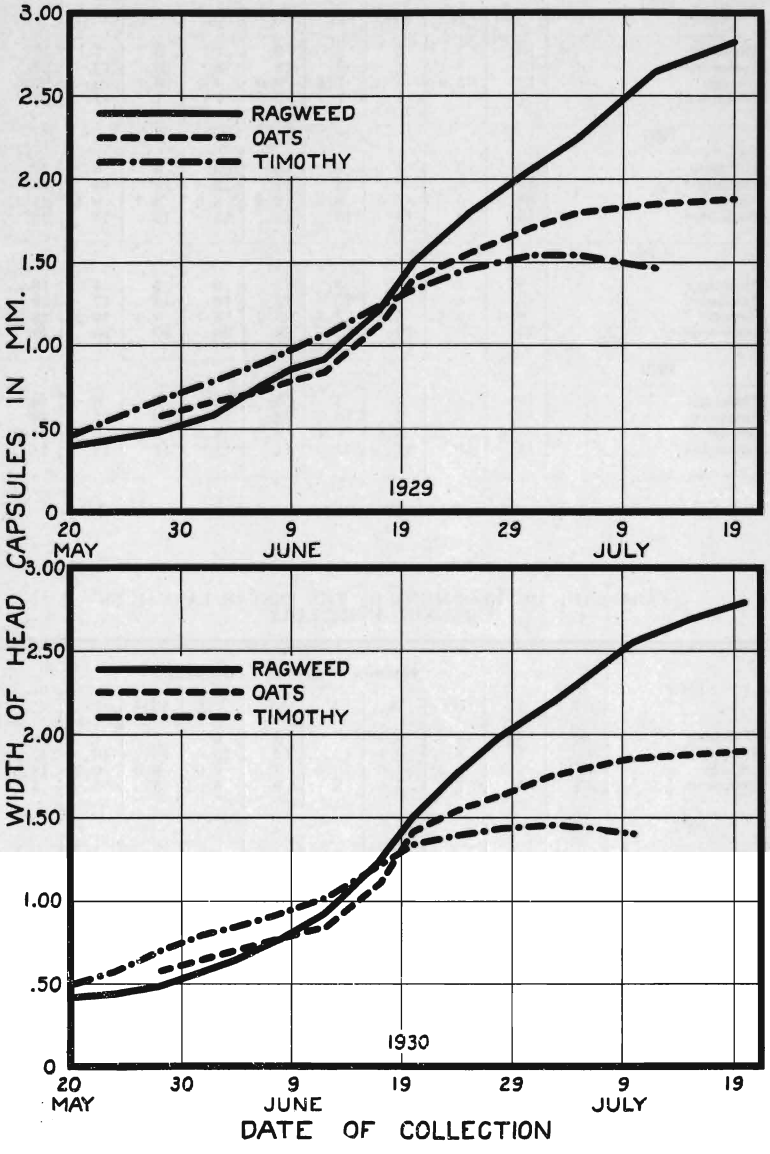

Fig. 15. A graph showing the effect of food (larvae feeding on different host plants) upon the rate of growth (as measured by the width of the head of the capsules).

Tables III, VIII, IX, X, XI and XII show the extent to which variations in the number of molts influence the length of larval life.

When the length of larval life of males and females having the same number of instars is compared the males are found to have the longer larval period, but when the total length of larval life for all males and all females is considered the females

TABLE VIII. DEVELOPMENT OF ALL SEVEN INSTAR LARVAE

Average	I	II	III	IV	V	VI	VII	Total
1926	11.3	5.5	6.4	7.7	9.3	11.1	23.6	75
1927	12.4	5.8	7.5	8.3	8.8	13.3	25.3	81
1928	9.7	6.0	6.7	7.4	8.5	11.4	26.5	76
1929	14.3	7.2	6.1	8.8	8.4	11.0	24.5	80
Average	11.9	6.1	6.67	8.05	8.75	11.7	24.97	78

TABLE IX. DEVELOPMENT OF ALL EIGHT INSTAR LARVAE

Average	I	II	III	IV	V	VI	VII	VIII	Total
1926	11.1	5.4	6.2	7.7	9.0	9.7	10.2	21.2	80
1927	12.2	5.7	7.1	8.4	8.8	10.4	9.9	22.9	85
1928	9.8	5.6	6.5	7.3	8.7	9.3	10.0	24.5	82
1929	13.9	7.4	6.3	8.3	8.6	9.1	9.8	22.7	86
Average	11.7	6.02	6.52	7.9	8.77	9.6	9.97	22.6	83

TABLE X. DEVELOPMENT OF ALL NINE INSTAR LARVAE

Average	I	II	III	IV	V	VI	VII	VIII	IX	Total
1926	12	5.2	6.0	7.4	9.0	9.1	9.4	10	20	88
1927	11.9	5.5	7.1	8.2	8.2	8.9	9.1	9.8	21.1	89
1928	9.6	6.1	6.2	7.3	8.0	8.7	9.3	10.2	22.5	88
1929	13.8	7.3	6.4	7.1	8.2	8.5	9.0	9.5	21.3	91
Average	11.8	6.0	6.4	7.5	8.35	8.8	9.2	9.9	21.2	89

TABLE XI. DEVELOPMENT OF ALL TEN INSTAR LARVAE

Average	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
1926	11.2	5.4	6.2	7.6	8.4	8.5	9.0	9.6	9.9	18.5	94
1927	12.5	5.5	7.4	8.3	8.0	8.4	8.2	9.3	9.8	20.0	97
1928	9.7	5.9	6.6	7.0	7.9	8.4	8.5	8.9	10.0	21.4	94
1929	14.3	7.0	6.1	8.2	7.9	8.4	8.4	9.0	9.3	20.1	99
Average	11.9	5.95	6.57	7.77	8.05	8.42	8.52	9.2	9.75	20	96

are found to have the longer larval period due to the fact that they very frequently have an increased number of molts. Under field conditions the total length of the larval stage varied from 60 to 130 days.

TABLE XII. DEVELOPMENT OF ALL LARVAE REARED IN SCREENED LABORATORY

No. of molts to complete development	Number of days in each stadium													
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
7	11.9	6.1	6.7	8.0	8.7	11.7	25							
8	11.7	6.0	6.5	7.9	8.8	9.6	10	23						
9	11.8	6.0	6.4	7.5	8.4	8.8	9.2	9.9	21					
10	11.9	5.9	6.6	7.8	8.1	8.4	8.5	9.2	9.8	20				
11	11.6	6.0	6.6	7.5	7.9	8.0	8.2	7.9	8.9	9.9	18			
12	11.8	6.1	6.4	7.7	8.2	8.1	8.4	8.0	7.9	8.7	9.3	19		
13	11.7	5.8	6.6	7.6	8.1	7.9	8.1	7.9	8.4	8.6	8.9	8.9	21	
14	11.9	6.0	6.4	7.4	7.8	8.2	7.9	8.3	7.9	8.5	8.2	9.1	9.4	18

PREPARATION FOR PUPATION

When a larva becomes full grown it usually deserts the plant and forms a small oval cell just below the surface of the soil. In a few instances, especially when the borer is feeding in corn, burdock or very large ragweed plants, pupation occurs in the larval feeding burrow. In such cases the larva drops to the bottom of the burrow where it prepares an oval cell. The old burrow is closed off with a partition of silk and frass and a new opening is prepared. In preparing this opening the larva leaves only the epidermis of the stem intact. When the pupal chamber has been prepared the larva passes into the prepupal stage. After spending from one to six days in this condition the insect sheds its last larval skin and the pupa is revealed.

PUPA

Immediately after transformation the pupa is creamy white in color, except that in many cases the cephalic region, head, thorax and appendages have a distinct greenish tint. In from one to three hours the abdominal segments and the dorsum of the thorax change to yellow or reddish yellow, and a few hours later the entire pupa assumes the normal reddish-brown color; then, for the next two or three days it retains a bright lustre which gradually disappears.

TIME OF PUPATION

Pupation normally begins late in July and continues until the last week of August. The earliest date of pupation was

July 17 (1927) and the latest Aug. 29 (1928); the time of pupation, however, is fairly constant from year to year and during the three-year period (1927-1929) the maximum variation from the above dates was 3 days (see table XIII).

There is a slight tendency for the males to pupate earlier than the females. This is indicated by the earlier arrival at the 50 percent point in the case of the males (indicated by asterisk in table XIII).

TABLE XIII. DATES OF PUPATION

Dates	1926		1927		1928		1929	
	Male	Female	Male	Female	Male	Female	Male	Female
July 17			1	2				
July 18			1	2				2
July 19			3	2			1	
July 20			4	1	1		1	
July 21	1	1		2	2	1		
July 22	1		4	2	2	1	12	8
July 23					7	2	4	3
July 24	1		2		3		8	2
July 25			3	4	4	2	6	6
July 26			2		6	3	7	5
July 27	1		5	2	9	2	5	9
July 28		1	3	2	7	1	16	6
July 29	4	2	3	2	4	1	12	10
July 30	4	6	2	4	4	1	15	12
July 31		4	2	3	2		12	9
Aug. 1	1	1		3	2	2	16	14
Aug. 2		1	4	2	3	1	13	9
Aug. 3		2	3	2	2		21	21
Aug. 4	3	1	8	8	2	6	9	11
Aug. 5	1	1	14	7	4	1	11	12
Aug. 6		1	6	7	6		8	11
Aug. 7			4	5	3	6	7	24
Aug. 8			16	10	6	10	18	21
Aug. 9	1	1	1	2	6	15	15	29
Aug. 10	1		1	1	8	11	20	46
Aug. 11	1	2	5	4	11	23	30	65
Aug. 12	1		4	6	7	11	18	32
Aug. 13		1	9	9	8	29	22	36
Aug. 14	1	1	6	8	20	22	14	27
Aug. 15			5	13	15	50	14	24
Aug. 16		3	2	5	36	85	8	23
Aug. 17			2	3	14	40	11	29
Aug. 18			5	14	3	24	20	37
Aug. 19			3	8	9	38	17	30
Aug. 20			1	8	3	10	11	30
Aug. 21			3	7	5	19	12	14
Aug. 22			5	4	2	7	2	22
Aug. 23			5	7	6	11	4	12
Aug. 24			2	2	1	1	3	10
Aug. 25				5		1	2	8
Aug. 26			1	6	1	1	2	5
Aug. 27				4		9		3
Aug. 28				2	1	2	2	1
Aug. 29						1		
TOTAL	22	30	153	190	235	450	429	678

DURATION OF THE PUPAL STAGE

The duration of the pupal stage of 2,083 pupae reared under normal conditions in the screened Insectary varied from 16 to 40 days, with an average of about 25 days (see table XIV).

TABLE XIV. DURATION OF THE PUPAL STAGE AT OUTDOOR TEMPERATURES

Days	1926		1927		1928		1929	
	Male	Female	Male	Female	Male	Female	Male	Female
16			1	3				
17			2	8				
18		1		7				
19		3	3	16				1
20	2	6	4	15	1	4		3
21	3	10	9	30	5	9	1	9
22	5	4	18	25	8	9	10	46
23	4	3	16	37	11	6	18	108
24	4		30	38	4	17	41	148
25	2		22	21	2	20	63	105
26			27	17	7	63	66	72
27			21	2	11	127	62	41
28			12	1	22	94	47	36
29			3		29	43	36	19
30			2		35	18	15	14
31			1		19	9	9	3
32					15	3	6	4
33					7	3	4	3
34					1		5	3
35					2	2	3	3
36					4	5	2	1
37					1	2	2	
38					2	4	2	
39					2	3	2	
40					1		1	
TOTAL	20	27	171	221	189	441	395	619

The length of the pupal stage is greatly influenced by the prevailing temperatures (tables XV and XVI). In 1926 the mean temperatures remained fairly uniform, and there was little variation in the length of the pupal stage (18-25 days). In 1927 the prevailing temperatures during August were moderately low and the pupal period varied from 20 to 30 days, but during the first two weeks of September the temperatures were above normal and the pupal period was short (16-21 days). In 1928 and again in 1929 there was a gradual fall in temperature from Aug. 1 to Oct. 1 and the length of the pupal stage increased from 20 days in August to 40 days late in September.

The relative humidity and the amount of moisture present in the soil did not seem to influence, at least to any marked

TABLE XV. DURATION OF THE PUPAL STAGE AT CONTROLLED TEMPERATURES

Temperature	Number of individuals	Male			Female		
		Min.	Max.	Av.	Min.	Max.	Av.
15°	20	24	31	26.5	22	29	25.1
20°	25	22	27	24.2	20	26	22.5
25°	25	20	25	21.6	18	23	20.5
27°	25	19	23	20.7	17	22	19.4
30°	25	18	21	19.3	16	20	18.1
33°	20	17	20	18.0	16	19	16.9

extent, the length of the pupal stage. One lot of pupae was divided and placed in two jars of sand, one of which was kept wet and the other fairly dry. Moths appeared in both cages at the same time, but many of those in the dry sand were deformed or otherwise abnormal.

TABLE XVI. EFFECT OF TEMPERATURE UPON THE DURATION OF THE PUPAL STAGE

Date pupated	Date emerged	Average time		Mean temperature
		Male	Female	
1926				
July 21	Aug. 13-15	25	23	74
July 27	Aug. 17-21	25	22	73.9
July 30	Aug. 20-23	23	21	73.9
Aug. 4	Aug. 25-27	23	21	73.5
Aug. 9	Aug. 29-31	22	20	74.3
Aug. 16	Sept. 4- 6	20	19	74
1927				
July 18-19	Aug. 8-12	24	21	72
July 27-29	Aug. 23-28	28	24	69
Aug. 8	Sept. 5	28	25	69
Aug. 14	Sept. 8	27	24	70
Aug. 23	Sept. 12	21	20	74
Aug. 25-27	Sept. 12-16	20	18	76
1928				
July 27	Aug. 17-18	22	21	75
Aug. 4	Aug. 28-30	26	24	73.5
Aug. 5-11	Sept. 2-10	29	26	70
Aug. 15-16	Sept. 11-15	30	28	69
Aug. 22-23	Sept. 21-28	33	30	65
Aug. 24-28	Sept. 28	40	37	62
	Oct. 5			
1929				
July 22-23	Aug. 13-16	24	22	74
July 25	Aug. 18-21	25	23	73
July 31	Aug. 24-26	26	24	72
Aug. 13-15	Sept. 9-11	28	25	70
Aug. 19-20	Sept. 15-17	29	27	67
Aug. 22	Sept. 20-22	32	30	65

As a rule the pupal stage of the males was from one to three days longer than that of the females (see tables XV, XVI, and XVII).

TABLE XVII. EFFECT OF SEX AND COLOR FORM ON DURATION OF PUPAL STAGE

Year	Male				Female			
	nitela	nebris	Total	No.	nitela	nebris	Total	No.
1926			22.56	20			20.81	27
1927	24.31	24.72	24.53	171	22.03	22.03	22.28	221
1928	28.96	21.21	29.00	189	27.55	26.99	27.41	441
1929	27.15	26.90	27.04	395	25.05	24.90	24.96	619

There appears to be an inverse relationship between the length of the larval stage, especially the last instar, and the length of the pupal stage. Very often the pupae developing

from late maturing larvae have a pupal period from one to three days shorter than pupae developing from early maturing larvae. The pupal records for 1926 (table XV) give further evidence of this inverse relationship. It may be noted that altho the temperature remained fairly constant thruout the season the length of the pupal stage became shorter as the season progressed (as the length of larval life became longer).

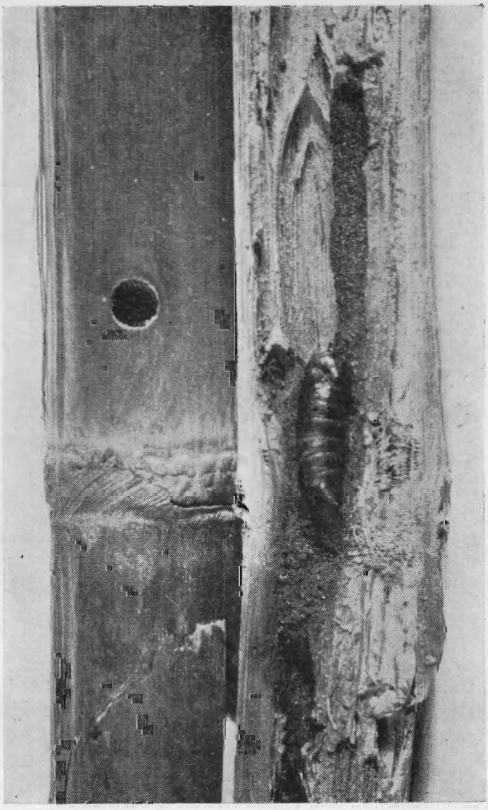

Fig. 16. Pupa of the stalk borer in a cornstalk. Note the entrance hole in the section to the left and the newly prepared exit with the epidermis intact at the left of the pupa.

In addition to the variations due to temperature, sex and length of larval life there is a large degree of variation in the length of the pupal stage, which is as yet unexplainable. In most instances individuals which pupated the same day and which were kept under similar conditions (often in the same container) showed variations of from three to eight days in the time of emergence. Of the 30 male individuals pupating Aug. 11, 1929; 1 emerged the 23rd. day, 3 the 24th., 6 the 25th., 7 the 26th., 6 the 27th., 3 the 28th., 3 the 29th., and 1 the 30th. day after pupation. The families showed approximately the same degree of variation. Similar variations were observed in pupae kept under constant conditions of temperature and relative humidity.

ADULT

EMERGENCE

Under normal conditions the pupa, while remaining in its earthen cell or at the base of its burrow in the stalk, splits the pupa case along the dorso-median line of the thorax, and the moth makes its escape. The newly emerged adult, with unexpanded wings, works its way thru the thin ceiling of its earthen cell, crawls upon some upright object where it stops to expand its wings. The expanding and drying of the wings requires from 30 to 40 minutes after which time they are dropped into their normal position and the moth is ready for its initial flight. If disturbed before the wings are fully indurated the moths run or flutter out of danger, after which they come to rest and then elevate the wings to complete the drying process. The time required to complete the whole operation of emergence from splitting of the pupal case to the folding of the wings varies from 45 to 85 minutes.

No observations have been made on the actual time of emergence in the field, but in out-of-door cages most of the moths emerged during the night. In the screened laboratory where the pupae were kept on a layer of moist sand in glass containers, the moths emerged at rather definite hours. Emergence usually began between 5 and 7 p. m., rose to an abrupt peak between 8:30 and 9 o'clock and then gradually dropped off until the last few emerged just before daylight. Emergence at night appears to be a photo-negative reaction. When pupae were placed in a brightly lighted room during the night and transferred to a dark room during the day the moths emerged between 8 and 11 a. m. A few moths emerging from pupae that were kept in continual darkness emerged at all hours of the day.

The emergence period lasts for about two months, beginning early in August and continuing until the first week in October (table XVIII). The earliest record was Aug. 6, (1927), the latest Oct. 5, (1928); and the peak or point of maximum emergence usually occurred during the first two weeks of September.

There is no marked difference in the time of appearance of the two sexes. As a rule, however, the male sex predominates for the first few days after which the females out-number the males (table XVIII).

PROPORTION OF SEXES AND MATING

Of the 2,335 individuals that have been reared during the four years covered by these experiments, 1,440 individuals or slightly less than 62 percent were females, while 895 individuals or a

TABLE XVIII. DATES OF ADULT EMERGENCE

Dates	1926		1927		1928		1929	
	Male	Female	Male	Female	Male	Female	Male	Female
Aug. 6			1	1				
Aug. 7				1			1	
Aug. 8				3				
Aug. 9								
Aug. 10			2					
Aug. 11			2	1			2	2
Aug. 12			4	1			1	
Aug. 13		1	1	1			6	3
Aug. 14			2	2			3	4
Aug. 15			6	2				
Aug. 16	1			1		1	7	4
Aug. 17					1	3	2	4
Aug. 18				2	7	3	1	5
Aug. 19		3	1	1	7	2	4	3
Aug. 20	2	6	2	1	9	1	1	2
Aug. 21	2	*4	2	3	3		4	6
Aug. 22	4	3	2	4	2		9	7
Aug. 23	*2	2	5	2	1	1	11	14
Aug. 24				2	5		15	13
Aug. 25		2	1	2	3		20	19
Aug. 26	1		*3	5	2	1	15	18
Aug. 27	3		2	1	2		12	11
Aug. 28			2	3	4	5	10	8
Aug. 29		1	5	9	2	1	12	23
Aug. 30	1	1	11	6	3	6	17	21
Aug. 31	1	1	9	8	3	3	11	21
Sept. 1		1	15	11	5	4	12	33
Sept. 2	2		6	8	8	23	17	43
Sept. 3	1		*7	3	4	5	*14	28
Sept. 4		1	7	12	7	2	19	32
Sept. 5			11	8	9	10	19	*35
Sept. 6		2	2	6	7	12	14	31
Sept. 7			10	*19	7	19	17	32
Sept. 8			10	12	13	17	17	25
Sept. 9			9	10	9	26	14	24
Spet. 10			7	13	*25	35	19	30
Sept. 11			13	23	10	52	14	26
Sept. 12			9	15	17	*52	15	17
Sept. 13			8	7	15	46	10	15
Sept. 14			1	3	23	49	6	8
Sept. 15			1	4	17	31	5	11
Sept. 16				4	15	34	7	24
Sept. 17				1	4	5	4	18
Sept. 18					5	1	8	13
Sept. 19					4	4	3	22
Sept. 20					6	9	4	9
Sept. 21					9	13	4	8
Sept. 22					2	5	1	4
Sept. 23					1	2	1	2
Sept. 24					1	1		2
Sept. 25					1		1	3
Sept. 26							1	2
Sept. 27					1		1	2
Sept. 28						3	1	2
Sept. 29					1		1	1
Sept. 30							1	1
Oct. 1					4	8		1
Oct. 2					1			
Oct. 3						3		
Oct. 4					1	1		
Oct. 5					1	1		
TOTAL	20	27	179	221	282	500	414	692

*Fifty-percent point.

little more than 38 percent were males. The percentage of females for each of the four seasons was 57, 56, 63 and 64, respectively. In the field the proportion of sexes may be more

TABLE XIX. ABUNDANCE OF VAR. NEBRIS AND VAR. NITELA COMPARED.

Year	Male			Female		
	nitela	nebris	% of nitela	nitela	nebris	% of nitela
1927	108	43	71	146	58	71.6
1928	125	57	68.7	319	112	74.0
1929	236	69	77.4	335	112	74.9
Total	469	169	73.5	800	282	73.8

nearly equal. Many individuals from which pupation and emergence records were obtained were collected as full-grown larvae, and it is entirely possible that many males had pupated in the field and that the field collections were therefore unjustly weighted in favor of a larger female population.

Mating usually takes place between 8 p. m. and 2 a. m. on the first night after emergence, but when 1 or 2-day-old males were available mating frequently occurs within a few hours after the emergence of the female moth.

The female moth indicates her readiness for copulation by raising and projecting the tip of her abdomen. (Apparently an attractive odor is emitted.) Soon one or more males approach the female against the wind and after hovering about her momentarily he alights beside her or strikes at the elevated caudal tip of her abdomen while in flight. As soon as the male succeeds in clasping he reverses his position so that the two moths face in opposite directions. The moths usually remain in coition for 30 to 75 minutes, the average time being about 45 minutes.

POLYGAMY

There is considerable evidence of polygamy and polyandry among the moths. Many males have been mated with two or more females. Twenty-four out of twenty-five males made second matings, 9 out of 10 made third matings and 5 out of 5 made fourth matings. No attempt was made to secure more than four matings from an individual. In a few cases fertile females that had laid some eggs were observed to mate a second time.

TIME, MANNER AND PLACE OF OVIPOSITION

According to Smith (37), Wm. Beutenmuller was the first person to describe the egg and to observe the time and place of deposition. Previous to this time (1905) it was quite generally believed and not infrequently stated that the winter was passed in the adult stage and that the eggs were deposited singly upon the young host plants.

Egg deposition begins the first or second night following mating (usually the second or third night after emergence). Practically all of the eggs are laid between sundown and midnight; it is not uncommon, however, for a few moths to con-

tinue ovipositing until daybreak. Observations on caged specimens indicate egg laying is at its peak between 9 and 10 p. m.

The female gives the first sign of egg laying by fluttering around over the plants, apparently hunting for a suitable place to deposit her eggs. Upon alighting on a plant the tip of the abdomen is immediately curved downward and the apex of the ovipositor is used to explore every little crack and crevice. When a suitable place is found the moth comes to rest and deposits from 15 to 50 or more eggs. In most instances the moth places the eggs well down under the leaf sheath, into a deep crevice or in rolled or folded leaves where they are held in place and more or less covered by a sort of cement. Frequently the female will move about considerably while laying one batch of eggs, placing a few eggs in one crevice and a few more in another.

Altho grasses, especially dead grasses, are preferred for oviposition the moths readily oviposit on many other plants, particularly ragweed, pigweed, corn, dock, golden rod and in fact on nearly any of the common fence-row plants. Apparently the moths of *Papaipema nebris* do not possess an instinctive habit for depositing their eggs upon the food plants of their larvae and oviposition seems to be largely regulated by tactile stimuli. As previously mentioned a female about to oviposit uses the tip of her ovipositor to find a suitable place to deposit her eggs, and unless she is able to find a suitable crack or crevice no eggs will be deposited. Fertile females placed in empty glass or tin containers refused to oviposit until a suitable medium was added. The addition of smooth paper or leaves would not induce oviposition; folded paper or rolled and folded leaves, however, usually brought eggs. Dead leaves of corn, grass and weeds were greatly preferred for oviposition but in their absence many other substances, e. g., absorbant cotton, pieces of cloth, rough bark, empty pupa cases and the bodies of dead moths were used.

The moth's apparent preference for grasses may be accounted for in two ways. First, the leaves of grasses with their encircling sheaths and rolled and folded blades are especially inviting to the moths; and second, the moths most frequently spend the day hidden in the grass, and since they are not very active it is to be expected that many of them will remain there to deposit their eggs.

LENGTH OF OVIPOSITION PERIOD

The preoviposition period varied from one to seven days and averaged 3.8 days. The time of mating greatly influenced the length of the preoviposition period. Unfertilized females usually hold their eggs until just before death, when a portion of them may be deposited. When females 5 or 6 days old were mated oviposition usually began the same day or the day following

mating. Variations in temperature did not materially affect the length of the preoviposition period.

The oviposition period varied from 4 to 23 days and averaged 10.88 days. The moths do not always lay eggs every day during the oviposition period, but as a rule a female that has once begun to lay will deposit a few eggs each day until near the end of the period, when a few irregular skips occur. The length of the oviposition period is closely correlated with the length of adult life and is therefore greatly influenced by the environmental factors which influence the longevity of the moth (temperature and water supply).

The postoviposition period varied from none to 9 days and averaged 2.44 days. Nineteen out of eighty-five females laid eggs during the day on which death occurred.

NUMBER OF EGGS LAID

The daily rate of oviposition varied with different females and from day to day for each individual. Daily egg production varied from a minimum of 6 to a maximum of 725 eggs. In most cases the moths produced many eggs (200-500 daily) for the first three or four days of the oviposition period after which there was usually a gradual decline in the number of eggs laid daily. A few moths, however, had one or two days of light egg deposition preceding the peak; a few did not reach a peak until late in the oviposition period and a few had more than one peak.

The total number of eggs deposited by a moth during her life varied from 75 to 2,199 and averaged 879. The size of the moth and length of adult life were the most important factors in determining the total number of eggs that would be produced. Since the ovaries always contain some immature eggs in which the yolk has not yet been formed, it will be readily seen that maximum egg production can only be expected from those moths which live a full span of life.

LONGEVITY

The length of life of the moths is determined almost entirely by biotic conditions, especially by temperature and water supply. During hot weather the moths have a high rate of metabolism, the rate of egg production is high and the length of life is comparatively short (8-10 days), whereas during cold weather the rate of metabolism is reduced and the moths are much longer lived (20 - 30 days). Moths deprived of water invariably died in less than 10 days, and except during very cold weather most of them died within four or five days. Moths which received sugar water, or diluted honey solution lived no longer than moths fed pure water.

Adult males lived from 2 to 34 days and averaged 16.6 days; adult females lived 3 to 36 days and averaged 17.1 days.

FOOD OF THE MOTHS

In the field, moths were frequently observed sipping dew from leaves and they were occasionally observed taking nectar from clover and mint blossoms. It was also observed that moths in captivity fed readily upon either pure or sweetened water when it was sprayed upon the foliage in their cages. In all cases the searching moths appeared to come upon their food supply by chance rather than by a response to some external stimulus. Unfed moths placed only a few centimeters away from water or sugar solutions did not seem to know that it was there, and apparently they were not able to orient themselves and move toward the food. In the field no moths were ever attracted to sweetened baits.

GENERAL HABITS

During the day the moths are usually very quiet, remaining almost immovable in well-concealed places such as tall grass or thick weeds. The moths usually rest with the head downward and the wings tightly folded over the body and the supporting stem. When disturbed they may respond with a short sluggish flight but more often they feign death. Handling or prodding with a pencil may or may not cause the insect to show signs of life. Ordinarily they will not move unless considerable pressure is applied. If rolled upon their backs they remain motionless for several moments, usually until after the observer has gone away.

Shortly after sundown the moths become somewhat active and begin to flutter about among the plants. Their flights are short, sluggish and of an erratic zig-zag character. During the first hour of activity the entire attention of the moth is given over to feeding after which the females begin to oviposit and the males apparently alternate between feeding and searching for mates.

There are occasional published records of the moths of *Papaipema nebris* being attracted to lights but never in very large numbers. W. B. Turner (38) reports the collection of 2 males of *P. nebris* in a total catch of 3,152 moths.

SEASONAL HISTORY

The stalk borer is a typical one-generation insect and there is very little variation in its seasonal occurence. The eggs are laid on the leaves of grass and weeds during the late summer and early fall months (Aug. 20 - Oct. 15). These eggs overwinter on the plants and hatch the following May or June. The young larvae make their way into the young grass and weed plants where they feed until they kill or outgrow their host, when they migrate to new and larger-stemmed plants. Transformation to the pupa stage takes place in the larval feeding burrow or in an especially constructed cell just below the surface of the soil. The moths emerge during late August

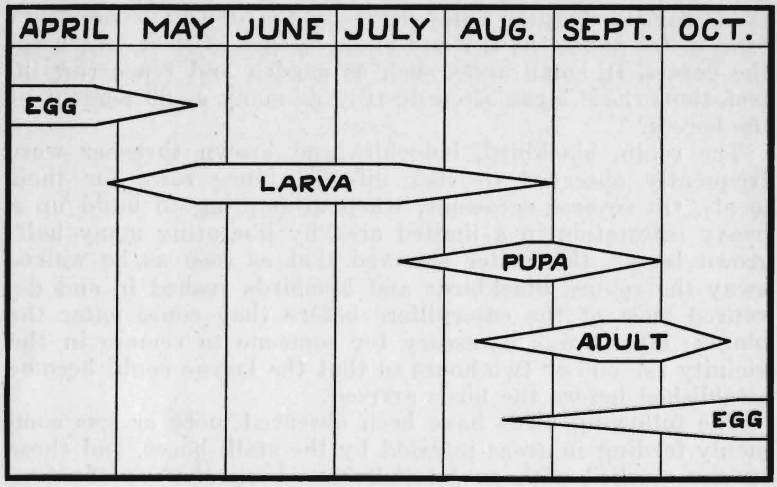

Fig. 17. Seasonal history of the stalk borer *Papaipema nebris* (Gn.).

and September and deposit their eggs on the leaves of dead grasses and weeds, where they remain until the following spring. The seasonal history is illustrated graphically in fig. 17.

NATURAL CONTROL

The abundance of the stalk borer is greatly influenced by several natural factors. Climatic conditions, birds, insectivorous mammals, insect parasites and predators and diseases all play an important part in reducing the numbers of this insect.

CLIMATIC CONDITIONS

Hot dry weather near the end of the incubation period prevents many eggs from hatching and kills many newly hatched larvae; on the other hand, heavy rains during the same period result in the drowning of many young caterpillars. Dry dusty weather during May and June destroys many first, second and third instar larvae thru dehydration, as they are forced to attempt migrations thru the dry dust. It is probable that sudden changes from very cold to warm and extreme cold temperatures during the winter destroy some over wintering eggs.

The weather also affects the borer population by its influence on plant growth and on the activity of parasites and disease organisms.

BIRDS

In late summer and early fall many corn, ragweed and other plants may be found with the main stalks shattered by num-

erous ragged angular holes made by the downy woodpecker (*Dryobates pubescens* L.) and allied species in their search for the borers. In small areas such as garden and fence row infestations these birds often destroy as many as 80 percent of the borers.

The robin, blackbird, bobwhite and brown thrasher were frequently observed to visit infested fence rows for their meals. On several occasions, when attempting to build up a heavy infestation in a limited area by liberating many half-grown larvae, the writer observed that as soon as he walked away the robins, blackbirds and bluebirds rushed in and devoured most of the caterpillars before they could enter the plants; and it was necessary for someone to remain in the vicinity for one or two hours so that the larvae could become established before the birds arrived.

The following birds have been observed more or less commonly feeding in areas infested by the stalk borer, and those species marked with an asterisk have been observed feeding upon the larvae.

*Bobwhite or quail (*Colinus virginianus*).
Yellow-billed cuckoo (*Coccyzus americanus*).
*Downy woodpecker (*Dryobates pubescens*).
Red-headed woodpecker (*Melanerpes erythrocephalus*).
Flicker (*Colaptes auratus*).
Kingbird (*Tyrannus tyrannus*).
*Blue jay (*Cyanocitta cristata*).
Bobolink (*Dolichonyx oryzivorus*).
Cowbird (*Molothrus ater*).
*Red-winged blackbird (*Agelaius phoeniceus*).
*Meadow lark(*Sturnella magna*).
*Blackbird or grackle (*Quiscalus quiscula*).
Catbird (*Dumetella carolinensis*).
*Brown thrasher (*Toxostoma rufum*).
*Robin (*Planesticus migratorius*).
*Bluebird (*Sialia sialis*).

MAMMALS

The skunk (*Mephitis nigra* Peale & Beauw.) frequently digs holes about the base of infested plants where it is searching for food, and it must be considered as a destroyer of larvae and pupae.

The short-tailed shrew (*Blarina brevicauda* Say.) is also a destroyer of the larval and pupal stages of the borer. These little animals frequently have many burrows or runways in grassy fence rows, and where these runways are numerous one has difficulty in finding live larvae or pupae even tho the plants above may have been very heavily infested. Larval head capsules and fragments of pupa cases can frequently be found in the digestive tract of the shrew.

Moles and field mice also destroy many larvae and pupae in the vicinity of their burrows and nests.

PREDATORY INSECTS

COLEOPTERA

Among the predaceous insects attacking the borer the lady-bug beetles (*Coccinellidae*) and the ground beetles (*Carabidae*) are of greatest importance. It is important to note that these predators are active at a time when they are least in competition with the other parasites and predators. The coccinellids are active early in the spring before the parasites appear, and the carabids attack the mature larvae that have apparently escaped parasitism and are about to pupate.

The coccinellid beetles especilly *Megilla maculata* De G., *Hippodamia convergens* Guer., and *Coccinella novemnotata* Host. altho small and not especially ferocious appear at a time when they are able to destroy many borers. The adult beetles emerge from hibernation early in the spring when food is scarce, and, as a result, they feed to a considerable extent upon the overwintering eggs of the stalk borer and other insects. Later in the season they attack the first and second instar larvae, but as a rule third and fourth instar larvae are able to fight them off and escape. Since the beetles normally hibernate in protected grass lands and fence rows where the stalk borer eggs are most abundant, it is to be expected that they will destroy many of these eggs. The following common coccinellids very frequently hibernate in grass lands heavily infested with *Papaipema* eggs. Those marked with an asterisk were observed feeding upon the eggs.

**Megilla maculata* De Geer.
**Hippodamia parenthesis* Say.
Hippodamia 13-punctata Linn
Hippodamia glacialis Fabr.
**Hippodamia convergens* Guer
**Coccinella 9-notata Hbst.*
**Coccinella trifasciata* Linn.
Coccinella sanguinea Linn.
**Coccinella transversoguttata* F
**Adalia bipunctata* Linn.
Chilocorus bivulnerus Muls.

Several species of carabids feed upon the larvae and pupae of the borer. The "fiery hunter" (*Calosoma calidum* Fab.) (fig. 18), the largest and most ferocious of the carabids attacking the borer, is very active and is capable of destroying several mature larvae daily. Full-grown larvae and adult beetles normally consume about one full-grown caterpillar each day,

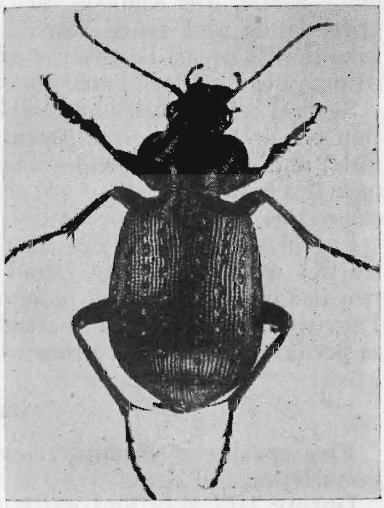

Fig. 18. The "fiery hunter" (*Calosoma calidum* Fab.) is an important enemy of the stalk borer.

but apparently they are always ready to fight and they will attack the caterpillars almost as fast as they come to them. Newly emerged adults in cages, have been observed to kill 12 full-grown borers in one day. It is unfortunate for the stalk borers that these hostile larvae become full-grown and the hungry adults emerge about the same time that the stalk borers enter the soil to pupate.

Pasimachus elongatus Lec. a large black carabid with a blue margin on the thorax and elytra was found to be very common in fence rows especially in loamy soil and where there was a moderate amount of trash. The immature stages have not been observed, but the adults destroy many borers.

Scaraties subterraneues var. *substriatus*, Hald., *a large black* beetle, was common in grass lands and fence rows. Like the Calosoma beetles the adults were ferocious and destroyed many caterpillars that happened to cross their path.

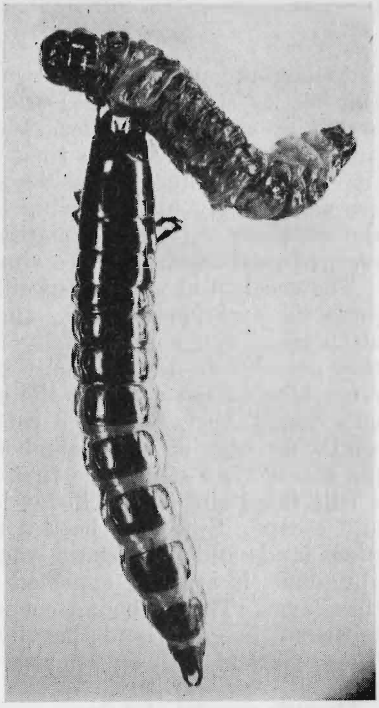

Fig. 19. A carabid larva attacking a stalk borer larva.

Several other species of carabids including, *Dicaetus elongatus* Bon., *Evarthrus colossus* Newm., *E. sodalis* Lec., *Galerita janus* Fab., and *Harpalus caliginosus* Fab. have been observed to attack the borers, but they are slow to act and are not to be considered as important predators.

Larvae of one of the fire flies (*Chauliognathus pennsylvanicus* De G.) were frequently found in *Papaipema* burrows, and in two instances they were observed attacking half-grown borers. They were also observed to attack parasite pupae and their value as predators is therefore somewhat questionable.

HEMIPTERA

Five species of Hemiptera were found feeding upon *Papaipema* larva and eggs.

During late May and early June adults of *Orius insidiosus* Say, were frequently observed feeding upon the eggs and newly

hatched borers. One *Orius* devoured nine *Papaipema* eggs in 13 minutes, but it was then apparently satisfied and no further feeding had occured at the end of an hour when observations of it were discontinued.

The *pentatomid, Podisus maculiventris* Say, is the most valuable of the predaceous *Hemiptera* attacking the stalk borer. Half-grown nymphs and adults are frequently found with the flaccid remains of a half-grown borer hanging on their beaks.

Adults of the nabid *Nabis ferus* Linn., and the *reduviids, Sinea diadema* Fab., and *zelus exsanguis* (Stal.) attack the half-grown larvae, but the more nearly mature caterpillars are not molested by these bugs.

CHRYSOPIDAE

Larvae of *Chrysopa oculata* Say. have been observed feeding upon *Papaipema* eggs in the fall and in late spring. Caged specimens somewhat reluctantly attacked newly hatched larvae. It is very doubtful if they attack larvae in the field.

HYMENOPTERA

Two species of ants, *Solenopsis molesta* Say., and one undetermined species, frequently attack migrating larvae. As a rule several ants attack a single larva, and altho it may put up a good fight for a short time it is finally overpowered and carried away by the ants.

PARASITES

DIPTERA

Masicera senilis Mg. (*M. myoidea* R. D. of Coquillett) is by far the most valuable of all the parasites of *Papaipema nebris*. In many localities this fly parasitizes as high as 70 percent of the borers. The adults deposit living larvae on the host plant, usually near the entrance to the tunnel and it is left for the young maggot to find its host. Upon locating a borer the maggot attaches itself to the caterpillar and quickly burrows thru the skin of the host. The maggot feeds within the body cavity of its host until the borer is nearly full-grown, usually in the last instar, and then rapidly consumes most of the body tissues. After this the maggot makes its exit from the empty larval skin and within a few hours forms its puparium. The length of the pupal stage varies from 10 to 21 days and averages about 14. Adult emergence extends over a rather long period of time, beginning July 1 and continuing up to Sept. 15. Apparently this species passes the winter in the larval stage in some alternate host.

Usually but one fly emerges from a single host; the emergence of two flies, however, is fairly common and in a few cases three

flies have been reared from a single host. In cases where more than one fly developed in a caterpillar they were usually smaller than the others.

Pupation occurs either in the feeding burrow of the host or in the soil. *Euptromalus dubius* (Ashm), *Plesignathus* sp., and *Perilampus hyalinus* Say were reared as hyperparasites from the puparia of *M. senilis*.

Winthema quadripustulata Fabr., a common parasite of armyworms and cutworms, has been reared from *Papaipema* larvae and pupae on frequent occasions. This species is not a consistent parasite of *Papaipema* and apparently it only attacks the borer when other hosts are scarce or after the fly population has been built up during an armyworm or cutworm outbreak. When they do attack the borer, however, they frequently parasitize from 12 to 21 percent of the caterpillars. This percentage would undoubtedly be increased but for the fact that this species deposits eggs, usually on the thorax of the host, and the borers are therefore only susceptible to attack during migration periods.

Muscina stabulans Fall. was reared from *Papaipema* larvae in small numbers each season and many puparia of this species were found within the feeding burrows of the borer. A few specimens of this fly were reared from nearly all large field collections of host larvae.

Gymnochaeta ruficornis Will., a large tachinid fly, is a common parasite of last instar larvae. About the time a larva might be expected to pupate it frequently assumes a swollen appearance in the mid-body region, and in a short time a large maggot penetrates the integument. This species hibernates as a pupa within the feeding burrow of the host or in the soil. The adults emerge the following May.

Three specimens of the fly, *Lixus variabili* Coq., were reared from *Papaipema* larvae. The adults emerged July 15, 1928.

Sarcophaga helicis Tns. and *Saracophaga cimbicus* Tns. were reared in small numbers from *Papaipema* larvae.

Hypostena variabilis Coq. and *Exorista* sp. were reared from *Papaipema* larvae by Washburn (40), in Minnesota, but they have not been reared from this host in Iowa.

HYMENOPTERA

Apanteles papaipemae (Mues.) the most common hymenopterous parasite frequently parasitizes as high as 38 percent of the borers, but the average would be much lower, falling somewhere between 8 and 14 percent. The parasite larvae emerge from the host just prior to the time that it might be expected to pupate, usually after it has left the plant and entered the soil; they occasionally come out, however, while the host is still in its feeding burrow. Within a few hours the larvae spin their

white cocoons which are arranged parallel to one another and bound together in a compact mass. The adults emerge during July and August.

Microbracon furtivus (Fyles) is less common than the preceding species but was reared from stalk borer larvae collected from several different localities. The larvae spin their cocoons during September but the adults do not emerge until the following May.

Microbracon caulicola Gahn., a common parasite of *Pyrausta* larvae was reared from one *Papaipema* larva.

Microplitus gortynae Rly. was common in all localities and is probably the second most important *hymenopterous* parasite of the stalk borer. From 8 to 33 parasites emerged from a single host, the average being 21.4. The parasite larvae usually emerge from the host before it leaves its feeding tunnel and soon spin their characteristic ribbed cocoons beside the dying host. The winter is passed in the larval stage and pupation occurs during April or May. The adults emerge during May and June.

Lissonota brunnea (Cress.), a large ichneumon parasite, was reared in large numbers. Adults emerged from overwintering pupae during April. During the warm hours of the day or when placed in a heated room the adults were very active, but when the temperature dropped below 50° F. they became rather sluggish; they were still able, however, to show feeble movements of the legs and antennae at 30° F. It seems probable that there is a spring generation on some alternate host.

Amblyteles jucundus (Brulle), another large ichneumon, was reared from *Papaipema* larvae but in smaller numbers than the preceding species. Adults emerged during August and a few in September.

In addition to the hymenopterous parasites of the stalk borer mentioned above, the following species have been reported in the literature: *Microbracon lutus* (Prov.), (*Sagaritis oxylus* (Cress.), *Amblyteles laetus* (Brulle) and *Amblyteles orpheus* (Cress.)

DISEASES

Many borers were killed by wilt disease (organism unidentified). Invariably when large numbers of borers were placed in a common receptacle, then isolated and reared individually a large percentage of them died of this disease. Soon after death the bodies became discolored, changing thru brown to black. Within a day the body contents were reduced to a dark-colored liquid which gave off a very foul odor.

Fourteen larvae were killed by a fungus, *Cordyceps* sp. *Larvae* killed by this disease developed long white fruiting bodies a few days after death.

Another fungus, *Metarrhizum anisopliae* (Metsch.) Sorok., (fig. 20) was quite common on both larvae and pupae. Within a few hours after the death of the larva or pupa a white fungus growth appeared thru the spiracles and in a short time the body was covered with a green and white fungus growth. Later the whole mass became green.

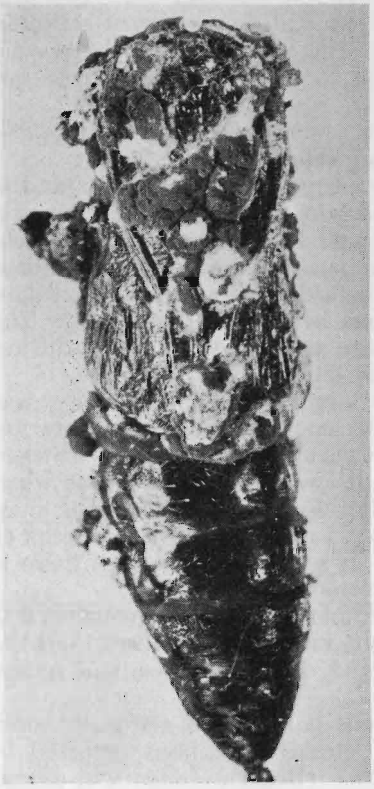

Fig. 20. A stalk borer pupa killed by a fungus disease.

ARTIFICIAL CONTROL

The control of the stalk borer calls for preventive rather than remedial control measures. After a field of corn, grain, potatoes, or any other crop of low cash return is found to be infested there is very little that can be done except to keep the plants in a healthy growing condition and attempt to offset the effect of the borers.

WEED CONTROL

It has been pointed out that the largest borer populations occur in fields and fence rows containing many large stemmed weeds, especially, giant ragweed (see fig. 21); and that pure stands of grass, clover and other small-stemmed plants will not maintain a borer infestation. It follows logically that the elimination of ragweed and other large weeds from the fence row is the most important single step in controlling the borer.

MOWING

Under certain conditions mowing of infested fence rows and waste lands may prove beneficial, but ordinarily mowing when the borers are active will increase the infestation in adjacent fields. Mowing during the second week in August, however, will remove the hiding places of the adults and ren-

Fig. 21. A fence row overrun with giant ragweeds. Hundreds of stalk borers develop in such a fence row.

der the locality undesirable for oviposition. If mowing earlier in the season is to be effective it will be necessary to remove the cut grass and weeds before they become entirely wilted. One farmer who makes a practice of mowing the roadside around his farm and hauling the hay in for feed before it is thoroly cured states that he has observed hundreds of half-grown borers come out of the grass and drop to the ground after the load had been hauled to the barnyard.

BURNING

Burning fence rows and infested grass lands between Nov. 1 and May 1, destroys the overwintering eggs and is one of the most practical means of control. Two years experiments with burning show that this method will reduce the borer population by 85 to 90 percent, and that burning in the spring is slightly more effective than burning in the fall (table XX). This is apparently due to the fact that dead leaves of corn and weeds on which many eggs had been deposited were blown into the control plots during the winter, and in that way the plots which were burned in the fall were reinfested.

MISCELLANEOUS TREATMENTS

After the borer has once entered a valuable plant the only means of saving the plant is by slitting the stem lengthwise and removing the offending caterpillar. This method will be

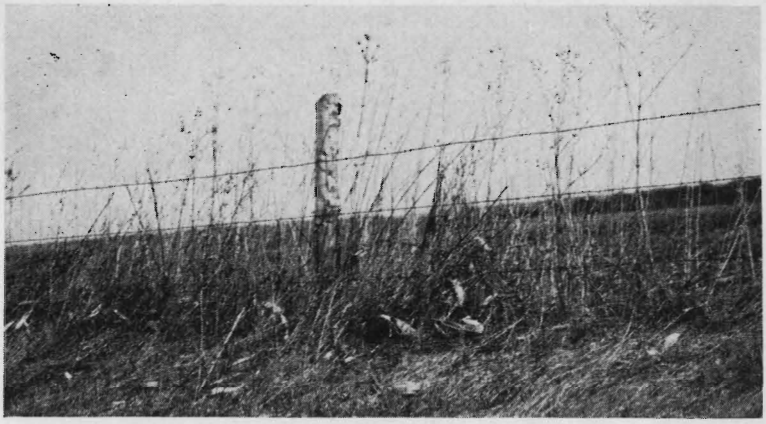

Fig. 22. A fence row of tall grass and weeds in early spring. Many eggs successfully pass the winter in such places.

TABLE XX. SHOWING THE EFFECT OF BURNING UPON THE BORER POPULATION IN A FENCE ROW

*Plot	Date burned	Borers per sq. yd.—July 15-20			
		1929		1930	
Plot 1	October	2		9	
Check 1	October		24		51
Plot 2	October	3		1	
Check 2	October		32		12
Plot 3	November	11		2	
Check 3	November		72		18
Plot 4	November	2		3	
Check 4	November		23		29
Plot 5	December	3		3	
Check 5	December		37		33
Plot 6	March	5		2	
Check 6	March		67		47
Plot 7	March	3		1	
Check 7	March		52		22
Plot 8	April	1		1	
Check 8	April		21		31
Plot 9	April	1		3	
Check 9	April		18		46
Plot 10	April	2		2	
Check 10	April		29		27

*Plot 1 for 1929 and Plot 1 for 1930 are distinct plots, but are referred to under number 1 to simplify the table.

found very helpful provided care is exercised to prevent destruction of the vascular system by cross section cuts. When the plants are seriously injured and the tops badly wilted, it is advisable to remove the plant and destroy it.

In many cases it is possible to kill the borer and save the plant by injecting ½ teaspoonful of chloroform, carbon tetrachloride or carbon disulphide into the entrance hole and then plugging the opening with moist clay. Under certain conditions, however, this treatment is frequently injurious if not fatal to many plants and is not to be strongly recommended.

Valuable plants may be protected by tanglefoot barriers. The tanglefoot may be applied directly to the base of the plant, but in most cases it seems preferable to surround the plant with a tin or cardboard collar 4 or 6 inches high and apply the tanglefoot to the upper 2 inches of this collar. If this type of barrier is to be effective the tanglefoot should be sticky at all times, and it is important that the upper portions of the plants do not come in contact with other plants which are not protected.

LITERATURE CITED

(1) BARNES, WM., AND MCDUNNOUGH, J.
1917. Check List of the Lepidoptera of Boreal America. 1-392.

(2) BEESLEY, THOMAS.
1823. Hessian Fly (Letter to Mr. Clarke) American Farmer V:165-166

(3) BEUTENMULLER, WM.
1901. Descriptive Catalogue of the Noctuidae Found Within Fifty Miles of New York City. Bul. American Museum of Natural History, **XIV**:229-312.

(4) BIRD, H.
1898. Notes on the Noctuid Genus Hydraecia. Can. Ent. **XXX**: 126-133.

(5) BIRD, H.
1902. New Histories and Species of Hydraecia. Can. Ent. **XXXIV**: 107-118.

(6) BIRD, H.
1921. New Species and Life Histories in Papaipema Sm. Can. Entomologist **LIII**:79-80.

(7) BRITTON, W. E.
1920. The Stalk Borer. Bul. Conn. Agr. Exp. Sta. 218.

(8) BRUNER, L., AND SWENK, M.
1907. Some insects Injurious to Wheat during 1905-1906. Bul. Neb Agr. Exp. Sta. 96.

(9) DYAR, HARRISON G.
1890. The Number of Molts in Lepidopterous Larva. Psyche V: 420-422.

(10) ———
1902. A list of North American Lepidoptera. Bul. U. S. Nat. Mus. 52.

(11) FELT, E. P.
1918. Corn and Grass Insects, N. Y. State Entomologist 34th rpt. 60-65.

(12) FITCH, ASA
1857. Entomology. Country Gentleman X:91.

(13) FORBES, S. A.
1905. Noxious and Beneficial Insects. Ill. State Entomologist, 23rd rpt. 1-273.

(14) FRANKLIN, H. J.
1908. Descriptions of Larvae and pupae of certain Species of *papaipema*. Minn. State Entomologist 12th rpt. (by F. L. Washburn) 197-200.

(15) GIBSON, ARTHUR
1913. Notes of Captures. Entomological Society of Ontario, rpt. **XLIII**:118-140.

(16) GROTE, A. R.
1874. List of the Noctuidae of North America. 1-77, Buffalo, N. Y.

(17) GUENEE
1852. Histoire Naturelle des Insectes Spec. Gen. des Lepidopteres T. 5. Paris, 1852.

(18) HAMPSON, C. F.
1910. Catalogue of Lepidoptera phalaenae in the British Museum. Brit. Museum (Nat. Hist.) Dept. of Zoology, London, **IX**:1-552.

(19) HARRIS, T. W.
1862. Insects Injurious to Vegetation. Flint Edition. 1-513, Boston.

(20) JENKENS, JABEZ
1840. Mediterranean or Fly-proof Wheat. The Farmer's Cabinet V:68.

(21) LE BARON
1872. The Stalk-Borer. Noxious Insects of Illinois 2nd. rpt. 141-142.
(22) LINTNER, J. A.
1872. Spindle Worms, Cultivator and Country Gentleman. **XXXVII**: 376.
(23) ———
1879. Report on Some Injurious Insects of the Year. Trans. N. Y. State Agr. Soc. **XXXIII**:142-164.
(24) ———
1882. *Gortyna nitela* Guen. New York State Entomologist 1st. rpt. 110-116.
(25) LOWRY, P. R.
1927. The Stalk Borer. Tech. Bul. N. H. Agr. Exp. Sta. 34.
(26) LYMAN, H. H.
1901. A New Gortyna, and Notes on the Genus. Can. Ent. **XXXIII**: 317-320.
(27) MORRISON, H. K.
1875. Notes on the Noctuidae, with Descriptions of Certain New Species. Acad. of Nat. Sci. of Phil. **XXVII**:55-71.
(28) RILEY, C. V.
1867. Dahlia and Aster Stalk Borer. Prairie Farmer **XIX**:116-117.
(29) ———
1869. The Stalk Borer, *Gortyna nitela* Guenee-noxious, Beneficial and other Insects of Missouri, 1st. rpt. 92-93.
(30) ———
1881. Lepidopterological Notes. Papilio **I**:106-110.
(31) RIPLEY, LEWIS BRADFORD
1923. The External Morphology and Post Embryology of Noctuid Larvae. Ill. Biol. Monog. **VIII**:243-345.
(32) RUHMAN, MAX H.
1915. Insect notes from Okanagan in 1914. Proc. Ent. Soc. B. C. 7-11.
(33) SHAFFER, J. M.
1890. Potato Stalkborer in Corn and Ragweed. Insect Life **II**:375.
(34) SMITH, EMMA A.
1877. The Stalk Borer-*Gortyna nitela* Guenee. Ill. State Entomologist 7th rpt. (By Cyrus Thomas) 112-114.
(35) SMITH, J. B.
1893. Catalogue of the Lepidopterous Superfamily Noctuidae Found in Boreal America. Bul. U. S. Nat. Mus. 44.
(36) ———
1899. Contributions Toward a Monograph of the Noctuidae of Boreal N. America, Revision of the Genus **Hydroecia** Gn. Trans. Am. Ent. Soc. **XXVI**:1-48.
(37) ———
1905. The Stalk Borer. N. J. Agr. Exp. Sta. 27th. rpt. 584-587.
(38) TURNER, W. B.
1920. Lepidoptera at Trap Lights. Jl. Agr. Research. **XVIII**:475-481.
(39) WASHBURN, F. L.
1908. Preliminary Report upon work with the Stalk Borers in Minnesota. Minn. State Entomologist 12th rpt. 151-155.
(40) ———
1910. Further work upon the Stalk Borers. Minn. State Entomologist 13th. rpt. 85-94.
(41) ———
1910. Notes on *Papaipema nitela* and *P. cataphracta*. Jl. Ec. Ent. **III**:165-168.
(42) WELDON, A.
1906. The Principal Injurious Insects of 1905. U. S. Dept. Agr. Yearbook (1905) 628-636.